Volume 24 APRIL, 1940 Number 4

# BULLETIN
## *of the*
# American Association *of* Petroleum Geologists

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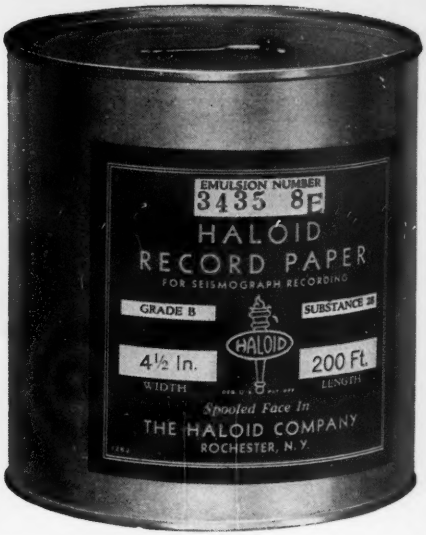


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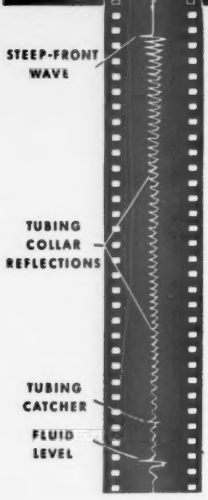


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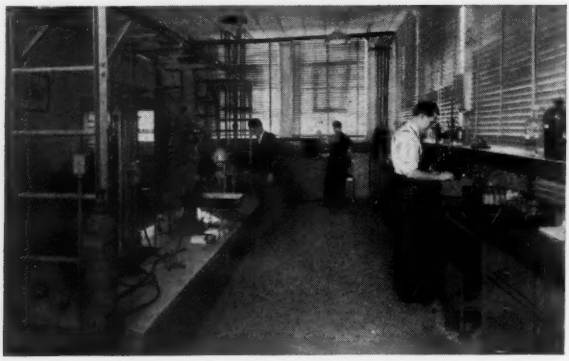

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Volume 24 Number 4

BULLETIN
*of the*
AMERICAN ASSOCIATION OF
PETROLEUM GEOLOGISTS

APRIL, 1940

# PERMIAN IN PARTS OF ROCKY MOUNTAIN AND COLORADO PLATEAU REGIONS[1]

ARTHUR A. BAKER[2] AND JAMES STEELE WILLIAMS[2]
Washington, D. C.

## ABSTRACT

A very thick Permian section in the Wasatch Mountains east of Provo, Utah, has been disclosed by field work of the Geological Survey in 1937 and 1938. This section appears to have special significance, for it offers promise of providing a key to the correlation of the Permian sequence of the southern Rocky Mountains and the Colorado Plateau with that of the northern Rocky Mountain region. The correlations and some of the age assignments of the Permian sequence of the Provo region suggested in this paper represent only tentative opinions and may be modified after the fossil collections from this area have been completely studied.

The Permian of southwestern Colorado and southeastern Utah consists of the Cutler formation (redbeds), above, and the Rico formation (redbeds and limestone), below; the Rico overlies the Pennsylvanian Hermosa formation. On the west, in southeastern Utah and northeastern Arizona, thick light-colored sandstone units are intercalated in the redbeds of the Cutler formation. Still farther west at the Grand Canyon in Arizona the Permian consists, in ascending order, of the Supai and Hermit formations (redbeds), the Coconino sandstone (light-colored, cross-bedded), and the marine Kaibab limestone at the top. Beds definitely of Pennsylvanian age are absent in part of the Grand Canyon region and the Permian rests on the Mississippian Redwall limestone. The Supai, Hermit, Coconino, and at least part of the Kaibab are believed to be continuous with, and essentially equivalent to, the Cutler formation. The Permian is unconformably overlain by Triassic beds—Moenkopi formation in southeastern Utah and northeastern Arizona and Dolores formation in southwestern Colorado.

The Permian deposits of western Wyoming, Idaho, and northern Utah, have generally been included in the Phosphoria formation, but in northwestern Wyoming they are placed in the Embar formation by many geologists; near Park City in northeastern Utah they are included in the Park City formation; and in parts of Wyoming they have been in part included in the Chugwater formation.

In its typical region in southeastern Idaho, the Phosphoria consists of an upper chert and limestone—the Rex chert member—and a lower phosphatic shale member. It is overlain by the Woodside shale of Lower Triassic age and underlain by the Wells formation of Pennsylvanian age. At the top of the Wells formation is a limestone generally thought to be of Pennsylvanian age. The lower part of the Park City formation in north-central Utah is considered by many geologists to be equivalent to the limestone at the top of the Wells formation farther north. The upper part of the Park City formation includes the phosphatic shale and upper cherty limestone that have been assigned to the Phosphoria formation farther north. The Park City formation has accordingly been considered by most geologists as in part of Pennsylvanian and in part of Permian age.

[1] Manuscript received, September 30, 1939. Read before the Association at the Oklahoma City meeting, March 22, 1939. Published by permission of the director of the Geological Survey, United States Department of Interior.

[2] Geologists, Geological Survey.

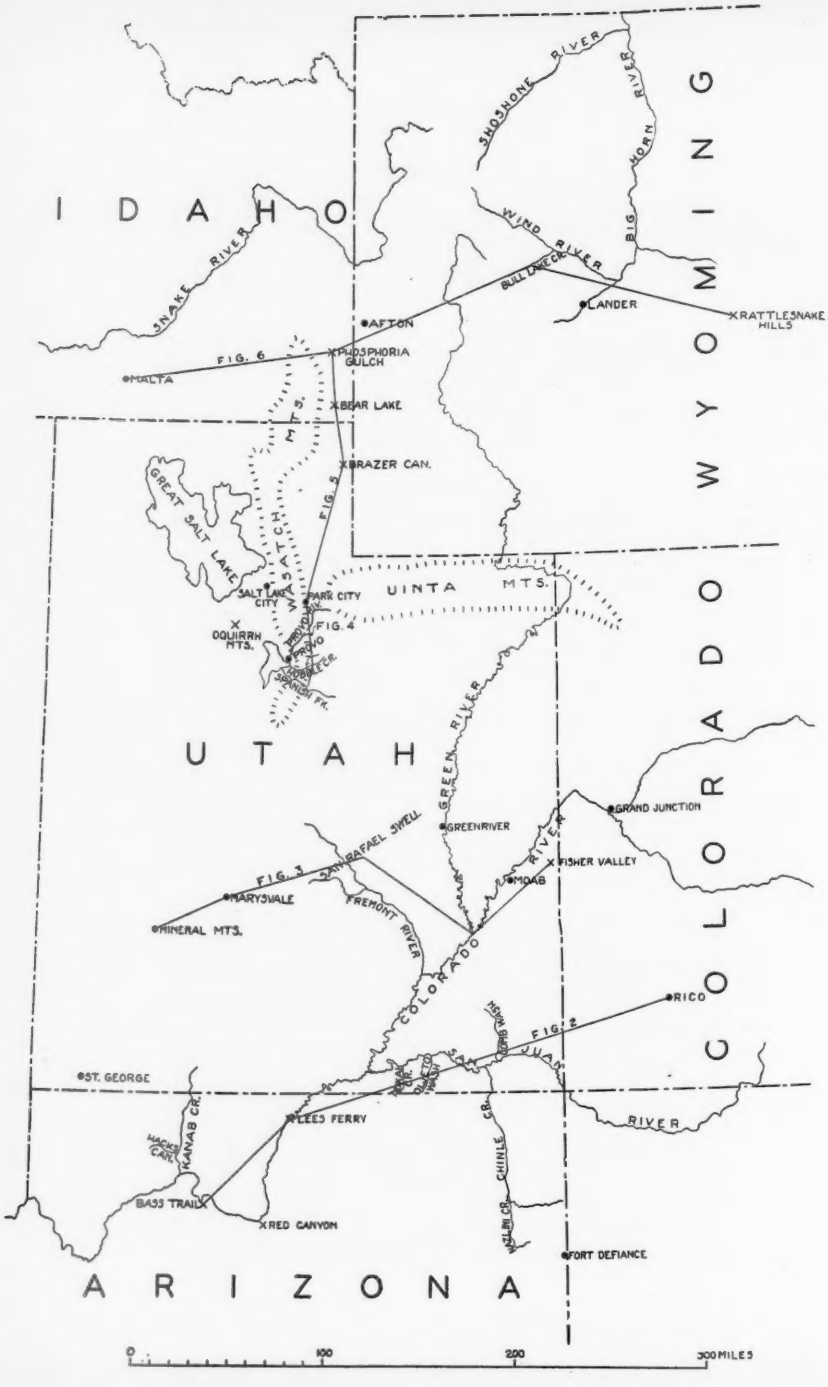



FIG. 1.—Index map showing location of sections presented in Figures 2–6 and of region included in Figure 7.

Between these two regions, in the vicinity of Provo, Utah, a series of rocks with a maximum thickness of more than 4,000 feet is included in the Permian, though the assignment of the two lowest units to the Permian is tentative. These rocks rest with probable unconformity on a tremendously thick Pennsylvanian section and are unconformably overlain by the Lower Triassic Woodside shale. Limestone at the base of the sequence considered Permian, in the Provo section, has a maximum thickness of nearly 1,500 feet but is absent locally. It has no counterpart in lithology in the Permian rocks of the Colorado Plateau to the south or in the Permian rocks that crop out toward the north in Utah, Idaho, and Wyoming. A red to gray sandstone, 600–1,000 feet thick, that overlies, and is gradational into, this limestone is similar in lithology to the Coconino sandstone and is tentatively correlated with it. Overlying the sandstone are nearly 2,000 feet of strata composed of a lower gray cherty limestone about 600 feet thick, an upper cherty limestone 600 to 1,100 feet thick, and an intervening black phosphatic shale about 200 feet thick. These rocks are considered by the writers to be the equivalent of the Park City formation. The discovery in them of a fauna that has in it definite Kaibab elements beneath typical Phosphoria faunas and lithology, suggests that the Kaibab is, at least in part, equivalent to the lower limestone and that the phosphatic black shale and upper limestone may not be represented by contemporaneous deposits in the Grand Canyon region of Arizona. It also casts doubt upon the correlation of the lower part of the Park City formation in northern Utah with the limestone at the top of the Pennsylvanian Wells formation in southeastern Idaho.

## INTRODUCTION

Field work in the southern Wasatch Mountains in north-central Utah during the summers of 1937 and 1938 has revealed the presence of an unusually thick sequence of rocks that offers promise of becoming the standard Permian section of much of the western United States and of providing a key to the correlation of Permian rocks in the northern Rocky Mountains with those of the Colorado Plateau of southern Utah and northern Arizona. Conclusions concerning the precise limits of the Permian and the correlation of the sequence with other Permian sections are only tentative, pending more extensive stratigraphic studies and a thorough study of the numerous fossil collections that have been made. However, it seems desirable to publish at this time a description of the section near Provo, together with additional data obtained on Permian rocks of near-by areas, and to present a preliminary correlation of the Provo section with other Permian sections north and south of it.

The stratigraphy of the Permian rocks studied is shown by a series of cross sections based on measured sections and finally by a composite correlation diagram. The location of the lines of cross sections is shown in Figure 1. The sections in the Colorado Plateau are described first, followed in order by the section in the southern Wasatch Mountains near Provo, and by sections across northern Utah, southern Idaho, and western Wyoming. The description of the Permian of the Colorado Plateau is, in large part, summarized from a published report by Baker and Reeside.[3] The Permian of the southern Wasatch

[3] A. A. Baker and J. B. Reeside, Jr., "Correlation of the Permian of Southern Utah, Northern Arizona, Northwestern New Mexico, and Southwestern Colorado," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 13 (1929), pp. 1413–48.

Mountains has been examined at many places by Baker and several sections have been studied by both writers of the present paper. The description of the sections in northern Utah, southern Idaho, and western Wyoming is based mainly on field work by Williams in collaboration with several other geologists of the Geological Survey.

## COLORADO PLATEAU

### BASS TRAIL, ARIZONA, TO RICO, COLORADO (FIG. 2)

The section from the Bass Trail in the Grand Canyon, Arizona, to Rico, Colorado, is illustrative of the shifting conditions of deposition and intermingling of sediments derived from different sources that are characteristic of the Permian stratigraphy of the Colorado Plateau.

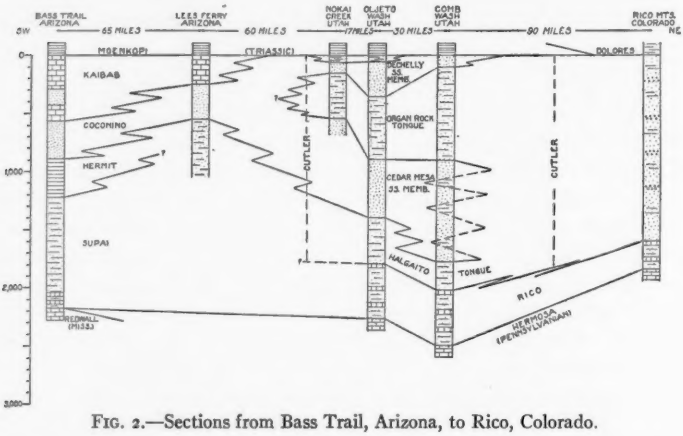



FIG. 2.—Sections from Bass Trail, Arizona, to Rico, Colorado.

The only beds known to be of marine origin are parts of the Rico formation at the base of the section on the east and the Kaibab limestone at the top of the section on the west. Limestone beds in the Rico contain a fauna which Girty[4] described as an eastern fauna comparable in a broad way to the faunas transitional from the Pennsylvanian to the Permian in Kansas. The Rico rests on the Pennsylvanian Hermosa formation. It is recognized as far west as south-central Utah beyond which it may be represented by part of the Supai formation. The overlying Cutler formation in the Rico Mountains consists of coarse-grained and conglomeratic arkosic redbeds derived from the pre-Cambrian of western Colorado. It does not contain beds of marine

[4] G. H. Girty, quoted in A. A. Baker and others, "Notes on the Stratigraphy of the Moab Region, Utah," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 11 (1927), pp. 793–94.

limestone which are characteristic of the underlying Rico formation and which serve as the principal basis for distinguishing these formations. The redbeds of the Cutler formation become finer-grained toward the west in southern Utah and northern Arizona, and intertongue with light-colored sandstone formed by sand derived from a source which lay on the west. The source of this sand was probably in part a land area in central and southwestern Arizona which was floored by pre-Cambrain quartzite, granites, and schists, as indicated by McKee.[5] However, the cross-bedding in the light-colored sandstone beds in southeastern Utah dips toward the southeast and it is inferred that the sand was derived in part from a source which was located on the northwest. This source may have been Pennsylvanian sandstone and quartzite exposed to erosion at some unknown locality on the northwest during at least part of Permian time. The light-colored DeChelly and Cedar Mesa sandstone members of the Cutler probably unite west of Nokai Creek to form the Coconino sandstone of the Grand Canyon region. Toward the west the Permian consists of the Kaibab limestone at the top underlain by the Coconino sandstone, the Hermit shale, and the Supai formation.[6] These formations as a group seem to be approximately the time equivalent of the combined Cutler and Rico formations of eastern Utah and western Colorado, although the shifting conditions of deposition and intertonguing of sediments illustrated by Figure 2 clearly demonstrate that few of the lithologic units of the Colorado Plateau Permian have constant time significance.

The Kaibab contains a marine fauna which has generally been considered to be of approximately the same age as the fauna of the Leonard formation of West Texas and, therefore, older than much of the Permian of that region. Consequently, the upper part of Permian time in the Grand Canyon area must be accounted for by the relatively inconspicuous unconformity at the base of the Triassic.

### MINERAL MOUNTAINS, UTAH, TO FISHER VALLEY, UTAH (FIG. 3)

The section from Mineral Mountains, Utah, to Fisher Valley, Utah, shows stratigraphic relationships similar to those shown in the previously described cross section farther south (Fig. 2). The Kaibab limestone thins eastward, presumably by gradation into light-colored Coconino sandstone which in turn splits into the White Rim and

[5] Edwin D. McKee, "The Coconino Sandstone—Its History and Origin," *Carnegie Inst. of Washington Pub. 440* (1934), pp. 104–06.

[6] L. F. Noble, "A Section of the Paleozoic Formations of the Grand Canyon at the Bass Trail," *U. S. Geol. Survey Prof. Paper 131* (1922), pp. 26, 29, 59.

Cedar Mesa sandstone members of the Cutler formation and then grades into redbeds of the Cutler. The writers have not visited the Mineral Mountains locality, but McKee[7] correlates in detail the Kaibab of that locality with the Kaibab of the Grand Canyon. The limestone section in the Mineral Mountains appears to be strictly comparable with the limestone series at Marysvale which was examined by the writers in company with Eugene Callaghan[8] and which Girty has correlated with the Kaibab. At both Marysvale and the Mineral Mountains the Kaibab is underlain by a quartzite, the age of which is unknown but which may be equivalent to the Permian sandstone present on the south or possibly to the quartzite of the upper part of the Pennsylvanian Oquirrh formation of north-central Utah. The Kaibab of the San Rafael Swell is thin and discontinuous

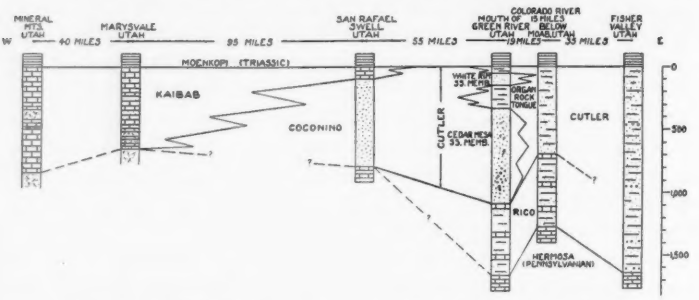



FIG. 3.—Sections from Mineral Mountains, Utah, to Fisher Valley, Utah.

and probably represents a late stage of deposition of Kaibab sediments near the original eastern margin of the formation. The fossils in the San Rafael Swell Kaibab are not altogether typical of the Kaibab limestone farther west, as pointed out by Girty[9] and McKee[10] who have observed in it some relationship to a Phosphoria fauna. During pre-Moenkopi erosion somewhat more of the Kaibab may have been removed toward the west than near the eastern margin of the formation and faunal characteristics of the San Rafael Swell Kaibab may be due to a slightly younger age for that part of the forma-

[7] Edwin D. McKee, "The Environment and History of the Toroweap and Kaibab Formations of Northern Arizona and Southern Utah," *Carnegie Inst. Washington Pub. 492* (1938), pp. 214–15, Figs. 6 and 20.

[8] Mr. Callaghan kindly supplied a measured section of the Kaibab at Marysvale.

[9] G. H. Girty, quoted in James Gilluly and J. B. Reeside, Jr., "Sedimentary Rocks of the San Rafael Swell and Some Adjacent Areas in Eastern Utah," *U. S. Geol. Survey Prof. Paper 150-D* (1928), p. 64.

[10] Edwin D. McKee, *op. cit.*, pp. 175–76.

tion. Interbedded sandstone and marine limestone beneath the Coconino sandstone in the San Rafael Swell have not been definitely identified, but presumably are equivalent to either the Rico or Hermosa. The Rico formation is the basal unit of the Permian along the lower course of the Green River and along the Colorado River south of Moab; but in Fisher Valley no marine limestone is present above the Hermosa formation, and there all the rocks between the Hermosa and the Moenkopi formations are included in the Cutler.

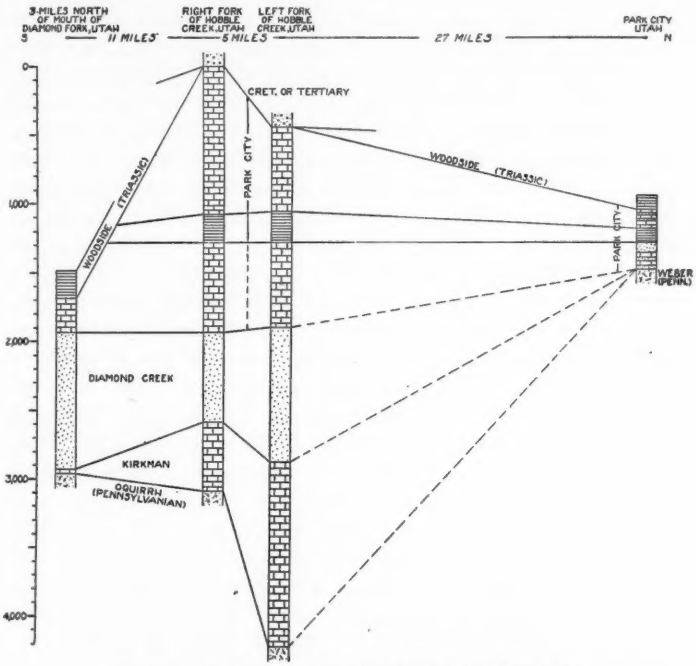



FIG. 4.—Sections along east side of Wasatch Mountains from Diamond Fork, Utah, to Park City, Utah.

### EAST SIDE OF WASATCH MOUNTAINS FROM DIAMOND FORK, UTAH, TO PARK CITY, UTAH (FIG. 4)

Three sections of the Permian rocks measured by the writers in the southern Wasatch Mountains and tentative correlations with the Park City formation of the Park City district are shown in Figure 4. The red shale of the Woodside, which is of Triassic age and equivalent to the lower part of the Moenkopi formation of the Colorado plateau

region, is the next youngest formation above the Permian except where the major unconformity at the base of the late Cretaceous or Tertiary conglomerate has cut below the Triassic. The Woodside shale is separated from the Permian by an angular unconformity and bevels across nearly 2,000 feet of Permian beds in a distance of about 10 miles. Because of this unconformity, even younger Permian beds than those discussed in this paper may occur in the region, for at none of the localities so far examined does the Woodside shale rest on the Permian where the Permian beds have their maximum development.

The upper two limestone units and the intervening shale in the Permian section of Hobble Creek are designated the Park City formation, although it is not yet clearly demonstrable that each of the three units is continuous with similar units in the Park City formation at the type locality. The upper limestone consists of cherty, thin-bedded to massive, gray to pink limestone with some interbedded gray sandstone, red shale and siltstone. It has a known maximum thickness of about 1,000 feet on the Right Fork of Hobble Creek; the thickness decreases toward the north to less than 150 feet at Park City and on the south in the vicinity of Spanish Fork it is absent, having been cut out by the pre-Triassic unconformity. The middle shale unit of the Park City is mostly black shale but contains thin beds of black cherty limestone and some thin beds of oölitic phosphate. It is about 200 feet thick on Hobble Creek, 100 feet or less in thickness at Park City, and is cut out by the pre-Triassic unconformity in the vicinity of Spanish Fork. The upper limestone and the middle shale unit of the Park City contain the Phosphoria fauna, including *Punctospirifer pulcher* (*Spiriferina pulchra*) (Meek), *Spirifer pseudocameratus* Girty, and other characteristic species. The lower limestone of the Park City formation of the Hobble Creek area consists of thin-bedded to massive, gray to pinkish gray limestone containing some gray to white chert and some interbedded gray sandy limestone and limy sandstone. It is at least 600 feet thick on Hobble Creek, but only the lower 200 feet are preserved beneath the unconformity in the vicinity of Spanish Fork. This limestone contains abundant specimens of the Kaibab productid *Productus* (*Dictyoclostus*) *ivesi* Newberry, s.l. (*P. bassi* McKee and *P. ivesi* Newberry), incomplete specimens that probably belong to other Kaibab species, and some elements of the Phosphoria fauna, including *Leiorhynchus weeksi* (Girty), *L. weeksi nobilis* (Girty), and fragments and undetermined specimens of other species. The presence of the first named species in this limestone suggests that the limestone is at least in part equivalent to the Kaibab limestone of the Colorado Plateau. Hence there is evidence at this locality that in general the Phos-

phoria fauna overlies and is younger than the Kaibab fauna, although some Phosphoria species existed in Kaibab time. Evidently the Phosphoria sea is in part a late stage of part of the Kaibab sea. The lower limestone of the Park City formation in the Hobble Creek region can not be traced directly into the lower part of the Park City formation at its type locality[11] because of the intervention of a zone of thrust faults. At its type locality the lower part of the Park City formation has long been considered to be of Pennsylvanian age, an interpretation that finds support in recent work by Stewart Williams[12] farther east on the flanks of the Uinta Mountains. However, the fossils from the lower division of the Park City at the type and near-by localities are few and not especially diagnostic, and the determination of its age as Pennsylvanian is based largely on collections from a limestone or from limestones in approximately the same stratigraphic position farther north. Our discoveries suggest that a restudy of the fossils from these beds and their comparison with our recent collections from the Hobble Creek area might either disprove the correlations or suggest a reassignment of the beds farther north. It, therefore, appears to be desirable to use the name Park City for these beds in the Provo region until additional work is completed and more definite conclusions warranted.

A gray or buff to red, fine to coarse-grained cross-bedded sandstone, in large part lime-cemented and friable but locally with a siliceous cement, conformably underlies the Park City formation and is 600–1,000 feet or more thick. It is here named the Diamond Creek sandstone from outcrops in Sec. 22, T. 8 S., R. 4 E., near the head of Little Diamond Creek, a tributary of Diamond Fork, where it is 1,000 feet or more thick. The sandstone has not been recognized in the Park City district. The lithology of the Diamond Creek sandstone and its stratigraphic position beneath limestone beds considered to be equivalent to the Kaibab limestone strongly suggest that it is continuous with the Coconino sandstone of the San Rafael Swell.

A limestone that conformably underlies the Diamond Creek sandstone is tentatively included in the Permian. It consists of gray to black, in part sandy, fetid limestone, commonly finely laminated and locally containing some oölitic phosphate. A substantial part of the limestone at most outcrops shows brecciation, with recemented an-

[11] J. M. Boutwell, "Geology and Ore Deposits of the Park City District, Utah," *U. S. Geol. Survey Prof. Paper 77* (1912), pp. 49–52; and A. R. Schultz, "A Geologic Reconnaissance of the Uinta Mountains, Northern Utah, with Special Reference to Phosphate," *U. S. Geol. Survey Bull. 690-C* (1918), pp. 49–50.

[12] J. Stewart Williams, "'Park City' Beds on Southwest Flank of Uinta Mountains, Utah," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 23 (1939), pp. 82–100.

gular fragments of the finely laminated limestone oriented in diverse directions. This unit is here named the Kirkman limestone from exposures in the Right Fork of Hobble Creek at the mouth of Kirkman Hollow where its thickness has not been measured but is estimated to be greater than 500 feet. Its maximum thickness, which is about 1,350 feet, is in the Left Fork of Hobble Creek. Toward the south it thins rapidly, being absent locally between Hobble Creek and Spanish Fork, and only about 75 feet thick in Spanish Fork. The variation in thickness is interpreted to mean that it was deposited upon an uneven surface. It has not been recognized in the Park City district on the north. Relatively thin beds of similar limestone are present in the overlying Diamond Creek sandstone, and east of the line of sections shown on Figure 4, the sandstone seems to grade laterally into limestone of Kirkman lithology. A breccia of angular fragments of quartzite cemented in a sandy lime matrix is the basal bed of the limestone at many localities. The Oquirrh formation underlies the Kirkman limestone in the vicinity of Hobble Creek. It consists of interbedded quartzite, limestone, and sandstone, in large part, if not entirely, of Pennsylvanian age. The Weber quartzite, at least in part a lateral equivalent of the Oquirrh, underlies the Park City formation in the Park City district.

Preliminary examination of the fossils from the Kirkman has not disclosed sufficiently diagnostic elements to allow the precise age of the formation to be determined. The tentative assignment of the Kirkman limestone and the Diamond Creek sandstone to the Permian is based entirely on admittedly inconclusive physical evidence. An erosion interval of considerable magnitude at the top of the Oquirrh formation is suggested by the sharp change in lithologic types at that contact, by the presence of the breccia at the base of the Kirkman limestone in many localities, and by the great variation in thickness of the limestone. Oölitic phosphate, almost exclusively peculiar to the Permian in the Rocky Mountains, occurs in the Kirkman limestone. Also the Kirkman limestone seems to grade laterally and vertically into the overlying Diamond Creek sandstone, which is inferred to be continuous with the Permian Coconino sandstone of the Colorado Plateau.

The boundary between the Pennsylvanian and Permian would perhaps be considered by some geologists to lie within the quartzite series of the Oquirrh formation underlying the Kirkman limestone. The Oquirrh formation is enormously thick and is a fairly uniform lithologic unit without marked divisions. Fusulines are abundant in it but have not been found in the overlying rocks here considered Per-

mian. An incomplete study of the fusuline collections made by the writers from the Oquirrh formation has so far revealed only forms that may be either Pennsylvanian or lower Permian[13] but *Pseudoschwagerina*, which is considered by some geologists to be a Permian index, was identified by M. L. Thompson in 1936 from at least one collection made by H. L. Bissell[14] from the upper part of the Oquirrh. According to Thompson's interpretation the boundary between the Pennsylvanian and Permian could be placed somewhat below the top of the Oquirrh formation.

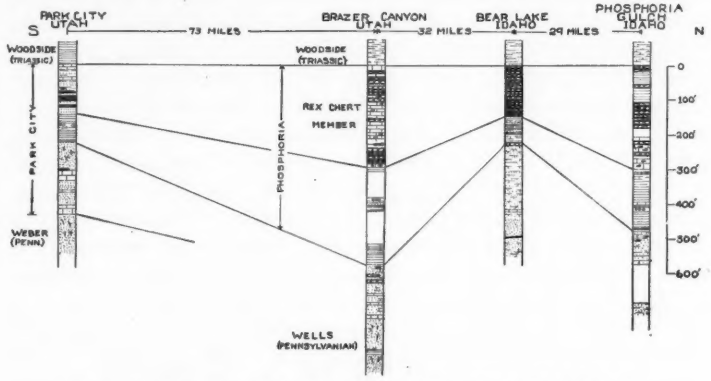



FIG. 5.—Sections from Park City, Utah, to Phosphoria Gulch, Idaho.

PARK CITY, UTAH, TO PHOSPHORIA GULCH, IDAHO (FIG. 5)

The cross section is a northward continuation of the cross section shown in Figure 4 and duplicates the section at Park City, Utah, on a large scale. It includes the type locality of the Park City formation near Park City, Utah,[15] and the type locality of the Phosphoria formation in Phosphoria Gulch, Idaho.[16] The upper member of the Park

[13] Fusulines identified by L. G. Henbest, Geological Survey. Further studies are in progress.

[14] H. L. Bissell, unpublished thesis, University of Iowa, p. 23, 1936. The following statement by M. L. Thompson is quoted in part from p. 23 of the thesis: "The rather robust fusulinids from the upper 500 feet of the section of the right hand fork of Hobble Creek canyon are referable to the genus *Pseudoschwagerina* Dunbar and Skinner (*Schwagerina* of authors) and the elongated fusulinids found in the same collection represent the genus *Schwagerina* Moeller, S. S. . . . The occurrence of *Pseudoschwagerina* and *Schwagerina* associated in these upper beds suggests very strongly that they are Permian in age and they probably should be referred to the lower portion of the Lower Permian."

[15] J. M. Boutwell, *op. cit.*, p. 49.

[16] R. W. Richards and G. R. Mansfield, "The Bannock Overthrust, a Major Fault in Southeastern Idaho and Northeastern Utah," *Jour. Geol.*, Vol. 20 (1912), pp. 683–89.

City is equivalent to the upper or Rex chert member of the Phosphoria. It varies greatly in lithology, as shown in Figure 5; at some places it is cherty limestone, at others alternating beds of limestone and chert, and at still others solid chert or chert and black silicious shale. Thick and thin sandstone beds and thin beds and lenses of phosphate rock also occur in it at some localities. The thickness of this unit in most places is less than 200 feet, but in a few places it exceeds 300 feet.

The middle black phosphatic shale member of the Park City is of fairly uniform lithology and rarely exceeds 300 feet in thickness. It is composed principally of dark shale, thin silty limestone and sandstone beds, and beds of phosphate, but in a few places has beds of chert and cherty limestone. The phosphate beds vary greatly in number and thickness, and most of them are lenticular within short distances.

The lower limestone at Park City has been considered for many years to be equivalent to a limestone bed that is present farther north and generally placed in the Pennsylvanian Wells formation. The lower part of the Park City formation has accordingly been classified as Pennsylvanian. The discovery of Permian fossils in the limestone beds below the black shale in the Hobble Creek area, within 20 miles of Park City, suggests that lower limestone of the typical Park City is also Permian. Possibly the lower limestone at Park City is not after all equivalent to the limestone at the top of the Wells in Idaho and adjacent regions, or perhaps the limestone at the top of the Wells is not a single unit but represents different beds in different regions, some of which are of Pennsylvanian and others of Permian age. Or perhaps the meager fossil evidence has been misinterpreted and the limestone at the top of the Wells, if a single unit, is not at any place of Pennsylvanian age. A review of paleontologic evidence gathered from the limestones at the top of the Wells at various places is in progress and may furnish new data on the age of the lower Park City limestone. The limestones at the top of the Wells seem to be more closely related lithologically to the underlying rocks than those in the lower Park City are to the underlying Weber.

The Permian rocks are overlain near Park City by the Lower Triassic red Woodside shale. Farther north and east tan to olive siltstone, silty sandstone and shale intervene between the Permian rocks and the red shale and in some places the red shale is absent. These tan to olive beds are generally referred to the Woodside and included in the Triassic. They have some lithologic resemblance to beds placed in the Dinwoody formation in western Wyoming, which is also gen-

erally considered to be of Triassic age, but in the opinion of some geologists may be in part or wholly Permian.[17]

NEAR MALTA, IDAHO, TO RATTLESNAKE HILLS, WYOMING (FIG. 6)

This cross section has an east-west trend and passes through Phosphoria Gulch, the type locality of the Phosphoria formation. The westernmost section was measured about 15 miles east of Malta, Idaho, in an area with numerous faults and folds that may have caused some duplication of beds. However, faulting or folding was not evident where the section was measured. Its thickness, with the top concealed, was determined to be more than 900 feet and is considered reliable. The Rex member here consists of black chert and thin, black siliceous shale. The underlying phosphatic shale is poorly exposed but is probably more than 400 feet thick, and rests on quartzite of the Pennsylvanian Wells formation. A short distance west and northwest of this section, Permian rocks are not present, and where they next occur in Idaho they are largely volcanic.

The Rex chert and phosphatic black shale thin eastward. Near Afton, Wyoming,[18] about 40 miles east of Phosphoria Gulch, the same divisions recognized at Phosphoria Gulch are easily recognizable, although differing somewhat in the details of lithology. In the Wind River Mountains, east of Afton, the Permian rocks were long included in the Embar formation of Darton and others,[19] and some geologists still include the Permian rocks in this region and especially in the Owl Creek and more northerly mountain ranges in the Embar formation. Others, however, place the part of Darton's Embar formation generally accepted as of Permian age in the Phosphoria formation, and the part considered to be of Triassic age in the Dinwoody formation. The typical divisions of the Phosphoria are not easily recognized in the Bull Lake Creek[20] section in the Wind River Mountains, mainly because thick limestone and sandstone beds are more abundant and the phosphate beds are not so conspicuous or so rich. A thin limestone that is near the base of the section at Bull Lake Creek and uncon-

[17] H. Glenn Walters, "Dinwoody Formation of Western Wyoming" (abstract), *Bull. Geol. Soc. America*, Vol. 42, No. 1 (1931), pp. 329; *Pan-Amer. Geologist*, Vol. 55, No. 3 (1931), p. 238.

[18] According to sections measured by W. W. Rubey and James Steele Williams.

[19] N. H. Darton, "Geology of the Owl Creek Mountains, Wyoming," *59th Congress, 1st session, Senate Document 219* (1906), p. 17, and numerous other uses by Darton, D. D. Condit, J. G. Bartram, W. T. Lee, and others.

[20] Data regarding this area are based mainly on joint field investigations by G. R. Mansfield, W. D. Keller, and James Steele Williams, on published work of several authors, and on personal communications of C. C. Branson.

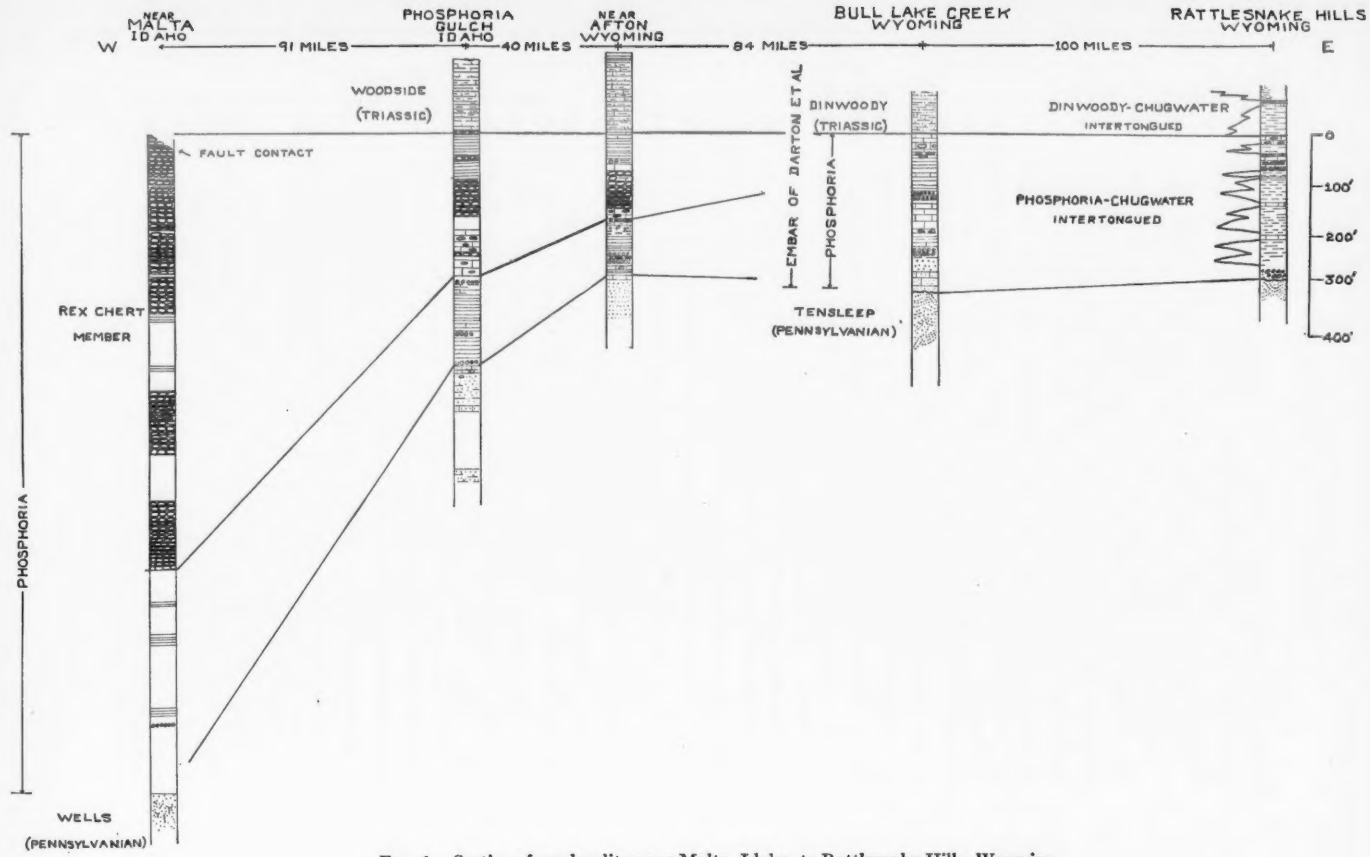



FIG. 6.—Sections from locality near Malta, Idaho, to Rattlesnake Hills, Wyoming.

formably overlies the Pennsylvanian Tensleep sandstone is tentatively placed in the Permian but its relation to the limestone beds in the upper part of the Wells formation of the sections farther west has not yet been satisfactorily determined.

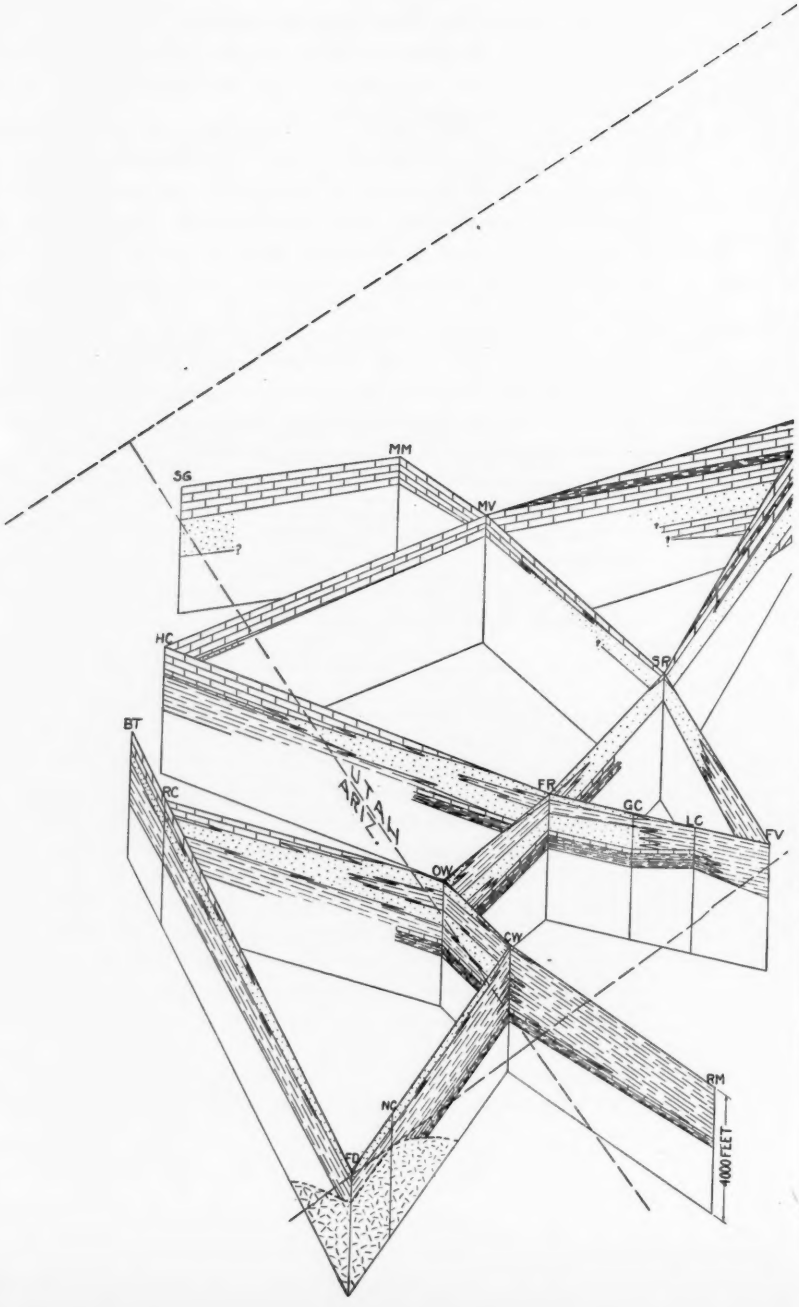
Eastward from the Wind River Mountains red shale, mudstone, and sandy siltstone, resembling at least superficially some of the redbeds of the Chugwater formation, are interbedded with dolomite and limestone containing faunules of Phosphoria age. These redbed units have been interpreted by Thomas,[21] whose section is shown in Figure 6, and by others as tongues of Chugwater sediments interbedded with tongues of Phosphoria and Dinwoody age. The writers have not visited the Rattlesnake Hills, but similar conditions have been observed in the mountains surrounding the Big Horn Basin in Wyoming. The general eastward change in the Permian rocks from fossiliferous marine beds in the west to non-fossiliferous or sparsely fossiliferous red mudstone, grit, and conglomerate in the east is characteristic of the Permian of the Great Basin, Colorado Plateau and Rocky Mountain provinces. This has been noted not only where sections in western Wyoming and Idaho have been compared with Permian sections farther east, but also in the study and comparison of sections in Utah and northwestern Arizona with Permian sections east of them in Colorado, Arizona, and New Mexico.

### COMPOSITE CORRELATION DIAGRAM (FIG. 7)

A generalized picture of the Permian stratigraphy of the entire region discussed in this paper is presented in the three-dimensional diagram, Figure 7. This diagram brings together into one composite picture the sections presented in Figures 2–6. In order to simplify presentation the minimum number of symbols for lithology has been used. Redbeds, regardless of whether they are sandstone or shale, are shown by the shale symbol, which is also used to indicate the black shale zone in the middle of the Park City formation and in the Phosphoria formation in the northern part of the area. Stippling is used to show the thick, light-colored sandstone units, and the conventional limestone pattern is used for units composed dominantly of limestone. Where chert is unusually abundant it is indicated by the standard pattern.

In parts of the region the correlations are based on many more data than are shown on the diagram and are considered to be firmly

[21] H. D. Thomas, "Phosphoria and Dinwoody Tongues in the Lower Chugwater of Central and Southeastern Wyoming," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 18, No. 12 (1934), pp. 1655–97.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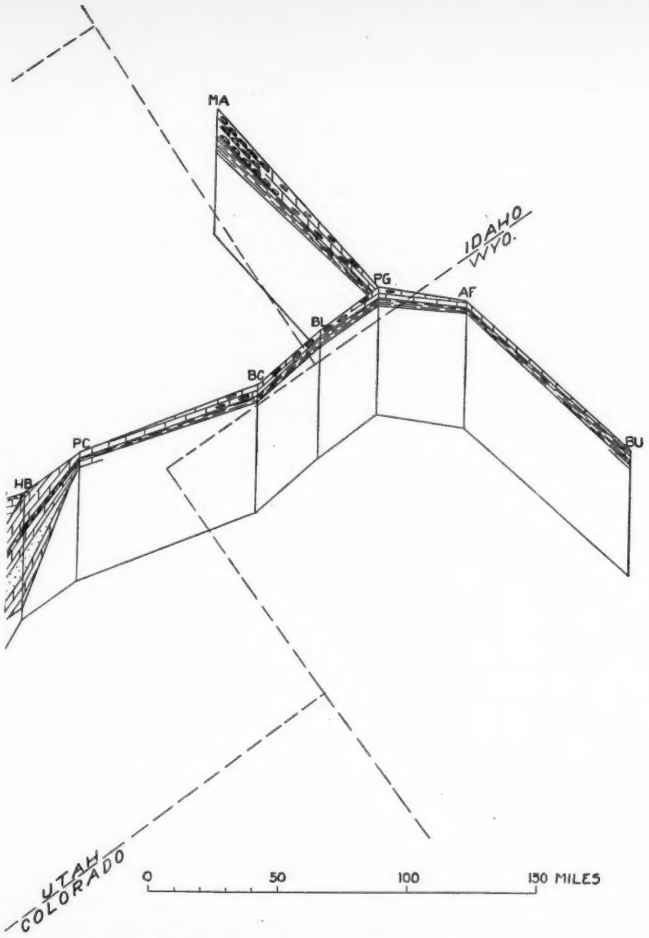


FIG. 7.—Composite correlation diagram showing relation of Permian deposits in parts of Rocky Mountains and Colorado Plateau region: *AF*, near Afton, Wyo.; *BC*, Brazer Canyon, Utah; *BL*, Bear Lake, Idaho; *BT*, Bass Trail, Ariz.; *BU*, Bull Lake Creek, Wyo.; *CW*, Comb Wash, Utah; *FV*, Fisher Valley, Utah; *GC*, mouth of Green River, Utah; *HB*, Hobble Creek, Utah; *HC*, Hacks Canyon, Ariz.; *LC*, Lockhart Canyon, Utah; *MA*, Malta, Idaho; *MM*, Mineral Mountains, Utah; *MV*, Marysvale, Utah; *NC*, Nazlini Creek, Ariz.; *OW*, Oljeto Wash, Ariz.; *PC*, Park City, Utah; *PG*, Phosphoria Gulch, Idaho; *RC*, Red Canyon, Ariz.; *RM*, Rico Mountains, Colo.; *SG*, St. George, Utah; *SR*, San Rafael Swell, Utah.

established, but in other parts of the region the correlation lines span large areas where the Permian rocks have been eroded or are buried beneath younger formations and where the correlations may be only inferred; no attempt is made to indicate the relative certainty of the correlations. Only rocks considered to be of Permian age are shown in the diagram with the exception of the pre-Cambrian crystalline rocks in the vicinity of Fort Defiance, Arizona (*FD*). The blank lower part of the fences represents Pennsylvanian or older formations, and the tops of the fences represent the contact between the Permian and the Triassic and are used as the datum plane.

The phosphatic black shale of the Park City and Phosphoria formations is present only in the northern part of the region. It is overlain in southern Idaho, western Wyoming, and northern Utah by the Rex chert member of the Phosphoria formation. This member is thickest near Malta, Idaho (*MA*), but thins eastward and southeastward. In northern Utah it grades laterally into the upper limestone of the Park City formation. This limestone thickens greatly in the vicinity of Hobble Creek, Utah (*HB*), but southward from Hobble Creek it appears to be cut out beneath the pre-Triassic unconformity; however, it is a possibility, even if a remote one, that the black shale unit of the Park City disappears southward under cover of younger rocks either by wedging out or by lateral gradation into different lithology so that the limestone at the San Rafael Swell (*SR*) and at Marysvale (*MV*) may possibly be in part equivalent to the limestone above the black shale at Hobble Creek (*HB*). The limestone considered to be the lower part of the Park City is thick in the vicinity of Hobble Creek, where it contains Permian fossils. Although limestone beds in the top of the Wells formation farther north have been thought to be equivalent to the lower Park City, they are not included in this chart as, so far as known, they do not contain Permian fossils and are not certainly equivalent. The lower limestone of the Park City formation is at least in part equivalent to the Kaibab limestone on the south, which is thick in southwestern Utah but decreases in thickness eastward and disappears in eastern Utah and eastern Arizona. The Diamond Creek sandstone is not recognized north of the vicinity of Hobble Creek but is shown as being continuous southward with the Coconino sandstone, which farther south splits into two thick light-colored sandstone units; these two sandstone units grade eastward in southeastern Utah into redbeds of the Cutler formation and toward the southwest the Coconino sandstone decreases in thickness. The light-colored sandstone in the lower part of the section in the vicinity of Saint George (*SG*) is

considered by Reeside and Bassler[22] to be almost entirely a Supai equivalent, which may correlate with a quartzitic sandstone beneath the Kaibab at Mineral Mountains (*MM*) and Marysvale (*MV*) that is not shown in the diagram. The redbeds of the lower part of the Permian in the vicinity of the Grand Canyon, Arizona (*BT* and *RC*), are considered to be equivalent in age to the redbeds in the lower part of the Cutler of southwestern Colorado (*RM*). The Rico formation at the base of the Permian in the southeastern part of the region is confined to a relatively small area in southeastern Utah, northeastern Arizona, and southwestern Colorado, with the eastern limit in Colorado and New Mexico. It may possibly be the time equivalent of the Kirkman limestone in the Hobble Creek region (*HB*).

[22] J. B. Reeside, Jr., and Harvey Bassler, "Stratigraphic Sections in Southwestern Utah and Northwestern Arizona," *U. S. Geol. Survey Prof. Paper 129-D* (1922), pp. 57 and 77.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 24, NO. 4 (APRIL, 1940), PP. 636-648, 2 FIGS.

# POSSIBILITIES OF HEAVY-MINERAL CORRELATION OF SOME PERMIAN SEDIMENTARY ROCKS, NEW SOUTH WALES[1]

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Crawley, Western Australia

## ABSTRACT

This paper describes and gives the percentage composition of the heavy-mineral residues of samples representing about 30 feet of coarse sandstone or grit obtained as core samples from a bore in Permian sediments at Kulnura, New South Wales. A search was made for varietal features of the minerals which might serve to distinguish a particular bed in the Permian of the Hunter River District with which to correlate the beds penetrated by the drill but the investigation was hampered by insufficient specimens of Permian sediments, by the great distance of the bore site from outcropping Permian beds, and by the similarity in heavy-mineral suites of all the Permian beds of the Hunter River District. This same heavy-mineral suite occurs in sediments from the lower Marine (lower Permian) to the Upper Triassic sandstones, thus indicating that there was continuous sedimentation in this area during a long period of time. The mineralogy of several members of the upper and lower Marine series is described for the first time, and several lines for further investigation are suggested. The necessity for examining a large number of specimens from well defined beds to obtain reliable mineralogical type residues is stressed as an aid in correlation problems of this nature.

## INTRODUCTION

At the beginning of 1939 a mineralogical examination was made of about 30 feet of grit or fine conglomerate which was encountered in a bore drill to test the possibilities of finding oil at Kulnura, about 37 miles southwest of Newcastle, the principal town of the Hunter River coal field, New South Wales.

Figure 1 shows that the bore started in Triassic rocks. It passed out of these at 2,700 feet and entered the upper Coal Measures, in which it continued to about 3,700 feet. From this depth to the bottom of the bore at 6,293 feet the upper Marine beds, in which the bore should have been, could not be recognized lithologically or by the scanty fossils. It is known that lithological variations are common to the upper Marine formations. As the fossil evidence was insufficient to fix the position of these beds, it was thought that a mineralogical examination of the bore cores, together with rocks from the upper Marine series, and the lower Marine series (Ravensfield sandstone), might be helpful.

## OUTLINE OF GEOLOGY

An outline of the stratigraphic succession is given so that the discussion of the problem can be followed.

[1] Manuscript received, September 11, 1939. Published with the permission of Oil Search Limited, Sydney, New South Wales.

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The formations of the Hunter River area with which this paper is concerned belong to the Triassic and Permian systems. They are subdivided as follows (11, p. 60; 5).[3]

| | | *Max. Thickness in Feet* |
|---|---|---|
| | TRIASSIC | |
| Hawkesbury series | (sandstones)..... | 1,000 |
| Narrabeen series | (sandstones, shales, tuffs)..... | 1,800 |

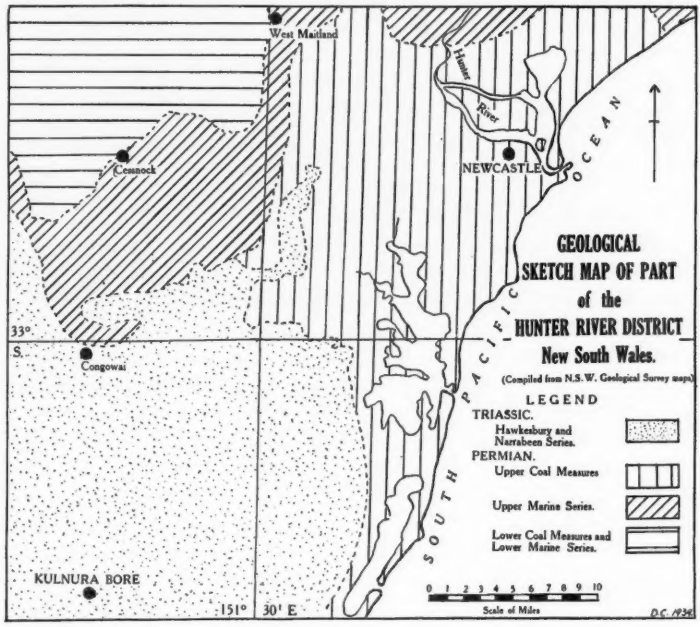


FIG. 1

| | | |
|---|---|---|
| | PERMIAN | |
| Upper Coal Measures | ..... | 5,300 |
| Upper Marine series | Mulbring (Crinoidal shales)..... | 3,000 |
| | Muree beds (marine tillite)..... | 400 |
| | Branxton beds (sandstone, shale, *Fenestella* beds) | 3,000 |
| Lower Marine (upper part) | Lower or Greta Coal Measures..... | 300 |
| | Farley stage, with Ravensfield sandstone..... | 1,000 |
| | Rutherford shales..... | 800 |
| | Harper's Hill conglomerates and tuffs..... | 270 |
| | LOWER PERMIAN OR UPPER CARBONIFEROUS | |
| Lower Marine (lower part) | Marine shales with *Gangamopteris* passing down into tuffs and sandstones with interbedded flows of basalt..... | 2,400 |
| | Lochinvar shales, glacial..... | 300 |

[3] Parenthetical references indicate Bibliography at end of article.

The Hunter River area was part of a large basin "of almost continuous sedimentation . . . from the Carboniferous time to the close of the Triassic Period." It is probable that highlands of Devonian quartzite and granite existed on the west and northwest as well as on the east, and that these supplied the material for the conglomerates and sandstones of the upper Marine and upper Coal Measures. Ultrabasic rocks of the Great Serpentine belt (about 90 miles north of the Hunter River area) were partly covered by the sea in upper Marine time, and may also have contributed material.

Later the Hawkesbury sandstones were laid down by rivers from a highland, depositing their detritus "in a lowland fronting depression, which was, at times, in the nature of a lake" (16, pp. 71, 73).

## MINERALOGY OF THE SEDIMENTS

### DESCRIPTION OF ROCKS EXAMINED

This investigation deals with the heavy minerals of six specimens of Kulnura grit (as the core samples are termed), two of the Muree beds, one Branxton sandstone, and four Ravensfield sandstones.

The Kulnura grit is a hard, gray, compact, calcareous grit, with occasional patches of black micaceous and pyritous mudstone, well-rounded quartz pebbles, fragments of dark sedimentary rocks, and pieces of brachiopod shells. It was thought that the bore was here in the Muree beds, but some doubt was expressed.

Two specimens of Muree bed were examined. One is a sandstone from the Congowai area (Fig. 1). It is a soft, reddish brown, micaceous, clayey, non-calcareous sandstone which yielded a large amount of heavy residue on separation in bromoform. The other is a specimen of Muree tillite from West Maitland, a hard, gritty, calcareous rock resembling the Kulnura rock. It also yielded a large amount of heavy residue.

The Branxton sandstone is soft, greenish, sandy mudstone, non-calcareous and slightly micaceous. It is from Rothbury Creek, $3\frac{1}{2}$ miles south of Branxton (Branxton is northwest of West Maitland and is just off the map in Figure 1). It yielded only a very small quantity of heavy residue, and the grains were very small in size. A special variety of zircon, and small prismatic tourmaline grains are characteristic of this specimen. Another Branxton rock, not examined mineralogically, is a coarse sandstone, but not as coarse as the Kulnura rock.

The Ravensfield sandstone is a fine to coarse-grained, greenish, slightly calcareous sandstone (5, p. 48). The coarser varieties somewhat resemble the Kulnura rock. Of the specimens examined, three

came from the Ravensfield quarry, about 3 miles due west of West Maitland, where the sandstone forms a bed 15 feet thick and is quarried for building stone, and the fourth from the Rutherford section.

On comparing specimens from the Muree, Ravensfield, and Branxton beds several points are to be noted.

1. The rather coarse-grained character of the Kulnura rock which in this respect resembles the Muree tillite from West Maitland, and differs from the coarse parts of the Ravensfield and Branxton beds in the cementing material
2. The Kulnura rock is calcareous, but the nearest outcropping Muree is non-calcareous, as are two specimens of the Ravensfield sandstone
3. There is an abundance of pyrites in the Kulnura grit and a little barite in some samples. There is no barite and very little pyrite in the Muree, Branxton, and Ravensfield sandstones

   The middle section of the Kulnura grit (6,276–6,277 feet) contains barite, which is absent in the lower specimens. Barite has been recorded (3, p. 361; 4, p. 84) from a sandstone in the upper Coal Measures and from some of the Narrabeen series in the Hunter River District.[4]
4. The Branxton sandstone examined is very much finer in grain size than the Kulnura grit or the Muree tillite

The details of the heavy-mineral residues are given in Table I.

*Method of Examination.*—Each rock was crushed in a dolly-pot, and the material passing an 85 B.S. sieve (approximately 70 mesh I.M.M.) was quartered until an easily handled sample, about 25–30 grams, was obtained. The fine rock flour was washed out and the remainder treated with *HCl* to remove the carbonates. Where pyrite was plentiful, $HNO_3$ was used instead of *HCl*. After washing and drying, each sample was placed in bromoform to separate the heavy minerals and the strongly magnetic grains were removed by a small electro-magnet. The residues were then mounted in clove oil and the minerals identified. The percentage composition of each residue was obtained by counting the grains in representative fields, between 400 and 500 grains being counted for each sample. The heavy minerals identified are listed in Table I, but the percentage figures refer only to the detrital minerals in the sediments, not to those which have arisen authigenically such as barite and pyrite, though logically leucoxene, anatase, and some of the rutile should also have been excluded. Some idea of the amount of each heavy residue is also given in Table I.

The matter of expressing the results of such examinations has been the subject of much controversy. If the mineralogical composition of a residue is expressed in percentages, it is more readily compared with the work of other investigators. If frequency numbers are used, after the percentages have been worked out by counts, they should be standard ones, for example, those of the Burmah Oil Company (7).

[4] Barite may or may not be a constituent of the grit as the writer is informed that it was added to the mud used in drilling.

### MINERAL SUITES

The heavy minerals, as listed in Table I, can be divided into two groups, the detrital constituents, and the authigenic constituents. The former indicate the provenance or types of rock contributing to the formation of the sediment; the latter, the conditions under which the sediments accumulated.

TABLE I

HEAVY MINERALS IN KULNURA, MUREE, BRANXTON, AND RAVENSFIELD SPECIMENS

| | *Kulnura* | | | | | | *Muree* | | *Branxton* | | *Ravensfield* | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Sample No.* | *1* | *2* | *3* | *4* | *5* | *6* | *7* | *8* | *9* | *10* | *11* | *12* | *13* |
| *Minerals* | *Per Cent* | | | | | | | | | | | | |
| Magnetite | | + | + | | + | | | | | | | | |
| Ilmenite | 13 | 33 | 21 | 17 | 11 | 16 | 38 | 35 | 14 | 11 | 3 | 6.5 | 6.7 |
| Leucoxene | 22 | 23 | 31 | 31 | 32 | 29 | 23 | 25 | 27 | 40 | 32 | 31 | 32 |
| Pyrite | + | | + | + | + | + | | | | + | | + | |
| Zircon, rounded | 19 | 11 | 6 | 19 | 14 | 19 | 9 | 10 | 16 | 13 | 24 | 21 | 30 |
| Zircon, prismatic | 7 | 4 | 8 | 16 | 10 | 15 | 5 | 10 | 22 | 10 | 21 | 12 | 16 |
| Tourmaline, brown | 25 | 20 | 22 | 9 | 19 | 16 | 16 | 7 | 5 | 7 | 5 | 6 | 4 |
| Tourmaline, blue, gray | 5 | 4 | 7 | 5 | 9 | 4 | 4 | 3 | 2 | 2 | 2 | .5 | 1 |
| Rutile | .5 | | .5 | 2 | 1 | .2 | 1.5 | 2.7 | 7 | 6 | 6 | 2 | 5 |
| Anatase | 1 | 2 | 2 | .1 | | .1 | 2 | .2 | 1 | | 2 | 3 | 2 |
| Titanite | 5 | .5 | 2 | .5 | 2 | 1 | 1 | 1 | 1.5 | 4 | 7 | 7 | 4 |
| Garnet | | | | | | | | 3.5 | + | 1.5 | .5 | 10 | .25 |
| Monazite | 1.5 | .5 | | .1 | .2 | | | .2 | | | 1 | .7 | .7 |
| Epidote | .5 | .5 | | .1 | | | .2 | | | | | | |
| Chlorite | + | | | | | | | .5 | | 1.5 | | | |
| Picotite | | | + | | + | + | + | .4 | 1.6 | .35 | .3 | .35 | |
| Barite | + | + | + | | | | | | | | | | |
| Brookite | | | | | + | | | | | .35 | | | |
| Carbonate | + | + | + | + | + | + | | + | | + | | + | |
| Mica | | | | | | | + | | + | | + | + | + |
| Quantity of residue | M | S | L | S | S | S | L | L | VS | S | L | L | S |

M = moderate amount; L = large amount; S = small amount; VS = very small amount; + = present, but percentage not determined.

*Kulnura samples:* 1, 6,265 ft.; 2, 6,276 ft.; 3, 6,277 ft.; 4, 6,290 ft.; 5, 6,291 ft.; 6, 6,293 ft.

*Muree samples:* 7, sandstone from Hector's Trig. Congowai area; 8, tillite from Campbell's Hill, West Maitland.

*Branxton sample:* 9, sandstone from Rothbury Creek, 3½ miles south of Branxton.

*Ravensfield samples:* 10, 11, 12, sandstone from Ravensfield quarry; 13, from the Rutherford section.

*Detrital minerals.*—The detrital minerals include all those which have been transported and incorporated in the sediments by the ordinary methods of sedimentation. The detrital minerals in the list are: magnetite, ilmenite, rutile (in part), titanite, zircon, tourmaline, epidote, chlorite, garnet, monazite, and picotite. Some of these minerals are of such wide distribution in the sediments of the district (4, p. 102), that they are of little use for correlation purposes, whereas others, picotite, for example, point to some different kind of rock which was brought under contribution when the sediments were being laid down. In Figure 2 the percentage of zircon and of tourmaline is shown as varying considerably throughout the specimens, and this may afford a means of correlating the different beds when a larger number of specimens have been examined. The colors, degree of

rounding, and other special features of the grains may also be useful in describing and comparing these rocks. Some of the mineral grains have been derived fairly recently, that is, recently in Permian times when these sediments were laid down, whereas the worn character of others testifies to their presence in pre-existing sediments which were eroded to form these sediments. A variation in amount of rounded and prismatic zircon is shown in Table I.

The varietal features of some of the heavy minerals may be of use in suggesting a source for the materials, or in comparing one sediment with another. Only those minerals which appear to have some diagnostic value are mentioned, as the detailed mineralogy of some of the upper Marine beds has already been described (4).

*Magnetite.*—Magnetite is present in many of the samples, but has no varietal features of interest, except that it may have come from the ultra-basic rocks along with picotite (4, p. 95). It is not always present in sediments and therefore may serve to distinguish these from others.

*Zircon.*—Zircon is an interesting and important mineral in all the residues both of the Kulnura and of the other sediments from the district. It makes up from 14 to 36 per cent of the residues in the Kulnura rocks, and rather more in the Ravensfield sandstone. There are a great number of varieties, some of which may be of diagnostic value. There are several varieties which serve to distinguish the residues as a whole. These are A, B, C, and D, listed here.

A. Rounded grains. Generally stumpy, robust grains, with inclusions. The rounding indicates derivation from pre-existing sediments
B. Thick, stumpy prisms, plus or minus inclusions
C. Purple grains, generally rounded
D. Rectangular prismatic grains, often worn and with practically no pyramids. Generally with inclusions
E. Grains with small prism faces and large acicular pyramids occur in Kulnura, 2, 3, 4, 5, 6; Muree, 8; Ravensfield, 10, 12, 13 (specimens numbered as in Table I)
F. Double-grains, two individuals which are joined parallel to the *c* crystallographic axis. Kulnurá, 3; Ravensfield, 10
G. Tabular almost equidimensional crystals with sharp, unworn edges. Kulnura, 4, 6; Muree, 8
H. Sharp pyramidal type, with the base of the pyramid joining the prism face very flatly. Muree, 7, 8
I. Acicular grains, some with central elongate inclusions. Kulnura, 2, 4; Ravensfield 11, 12, 13
J. A type with practically no prism faces, rather worn. Ravensfield, 11
K. Small sharp-edged prism and pyramid type, many with small inclusions. Branxton, 9; Ravensfield, 13.
L. Zoned grains. Kulnura, 2, 3, 5; Muree, 7, 8; Ravensfield, 12

Some of these varieties occur in all the specimens examined, but, as shown, several are restricted to one or two places. The ubiquituous varieties are A, B, C, and D. The zircons of the Ravensfield sandstone are generally rather brownish in color, and No. 12 contains greenish

grains which may be xenotime. A, B, C, and D indicate that these sediments were derived from one petrographic province. The small, sharp-edged prismatic grains (K) show that fresh granites or other acid igneous rocks contributed to sedimentation at some time. The purple grains (C) have probably had a long history. Elsewhere their source is known to be in pre-Cambrian gneisses, and they are of common occurrence in gneiss and in some sediments in Western Australia, where, however, the purple grains are large and generally zoned. The small rounded purple grains in the Kulnura and other Permian rocks from this district are similar to those occurring in British sediments and to those of the Moine schists and gneisses of Scotland.

*Garnet.*—Garnet occurs in the Ravensfield sandstone and the Muree tillite, and one or two grains were also seen in the Branxton sandstone. It is possibly derived from the rocks of the Great Serpentine belt (4, p. 98).

*Tourmaline.*—Tourmaline is plentiful, as shown by the percentage figures, the greatest amount being in the Kulnura rock. There are two noteworthy varieties, bright, yellowish brown grains, and light, watery blue, strongly pleochroic grains. Tourmaline occurs principally in angular broken fragments, but in every slide there are also some perfectly spherical grains. Parti-colored blue and brown grains were common in some residues, notably Kulnura 5, and one or two of the Ravensfield specimens. The well rounded grains have probably come in with the rounded zircon and represent material from an older sediment, but the angular grains and the prismatic (very plentiful in the Branxton sandstone) have had a shorter history and suggest that a later granitic terrain was eroded to produce the sediment.

*Titanite.*—Titanite is an interesting member of the suites and in some makes up a considerable part (Fig. 2). It occurs in colorless, chunky grains which are fresh and angular. Titanite is doubtless derived from granites and probably came in with the prismatic zircon, and angular tourmaline.

*Monazite.*—Monazite is of similar origin, but many of the grains are well rounded.

*Picotite.*—Picotite was identified only in small quantities although it has been stated to be present in larger amounts in other sediments of the area (4, pp. 82, 84). It points to the presence of ultra-basic rocks in the distributive province, this probably being in the serpentine belt aforementioned.

*Rutile.*—The well rounded, deeply colored rutile grains have been derived from some pre-existing sediment.

*Apatite.*—Apatite was not recorded, but if present, was sacrificed

in the acid treatment necessary to remove the carbonates. It is present in small quantities in places in the upper Marine sediments (4, p. 82).

AUTHIGENIC MINERALS

These are minerals which have arisen within the sediments during formation and consolidation, and include the carbonates, barite, pyrite, leucoxene, anatase, brookite, and some of the rutile. They point to the processes which have taken place during deposition of the sediment. Barite[5] indicates lacustrine conditions for Kulnura grit (8, p. 439); pyrite adds that these conditions were anaerobic and suggests that the environment was a semi-closed bay where there was little circulation of water. This is supported by the presence of shell fragments and of complete brachiopods (*Productus* sp.) in part of the Kulnura core. These conditions refer only to the Kulnura samples as the other rocks, except the Muree tillite, were laid down in much deeper water with muds and silt as well as fine sand. The gritty character of the Kulnura rock indicates a near-shore environment.

The titanium minerals are always interesting, for their changes indicate the conditions of their surroundings. Anatase and brookite (2) arise where sour (acid) conditions prevail and commonly accompany pyrite. Since leucoxene has been proved (9) to be of the composition either of anatase or rutile it is now easier to explain its abundance in some sediments than when it was considered to be a form of titanite. Pale yellow, amber, and orange, sharply crystalline rutile is also authigenic.

The percentage compositions of the heavy residues indicate that there are a number of well marked variations in mineralogy. Whether these variations are sufficient to distinguish the different rocks will have to be proved by the examination of a larger suite of specimens. Figure 2 shows the variations in the principal minerals of the residues, excluding the authigenic minerals such as barite and pyrites, because it was felt that the detrital grains would give better results for comparative purposes than if all the minerals of each residue were used. From Figure 2 it is seen that in the 30 feet of Kulnura grit there are well marked mineralogical variations. Whether the grit should be regarded as one bed or not could have been decided if the whole core (from the surface) had been available for examination. Lithologically the rock is of one type, a coarse gritty sandstone or fine conglomerate, with patches of muddy material. Figure 2 also shows that there is a variation in mineralogy in the Ravensfield specimens, three of which are from the same quarry.

[5] The Kulnura grit may be contaminated with barite from the mud used in drilling, hence its presence has no significance.

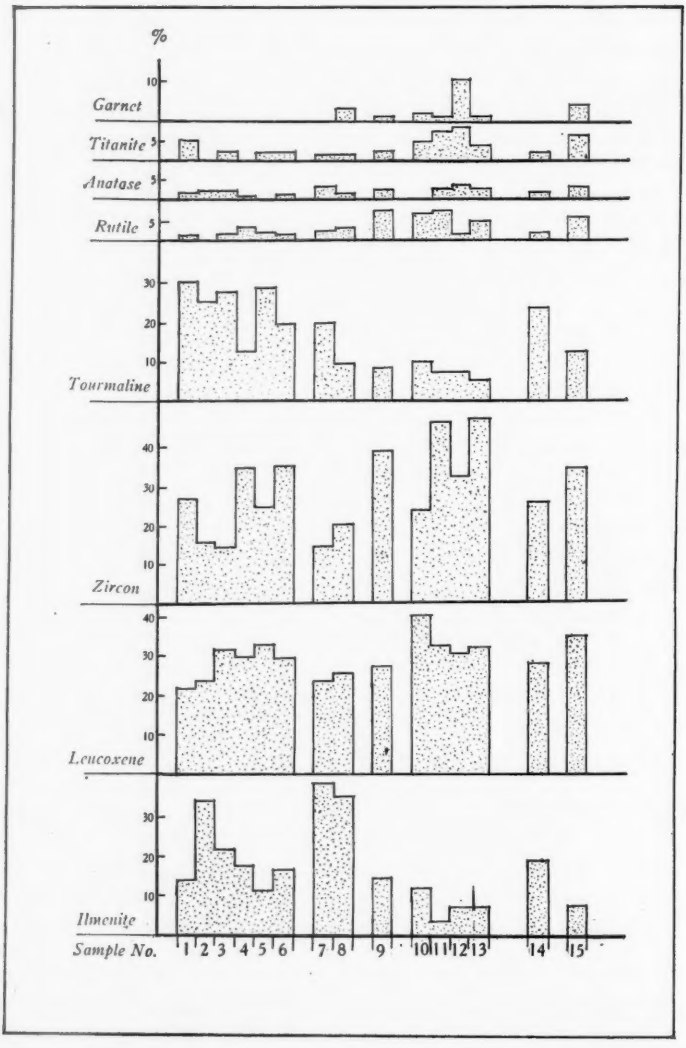


FIG. 2.—Diagram showing percentage composition of heavy residues of Kulnura, Muree, Branxton, and Ravensfield rocks (minor constituents omitted). (1, Kulnura, 6,265 ft.; 2, Kulnura, 6,276 ft.; 3, Kulnura, 6,277 ft.; 4, Kulnura, 6,290 ft.; 5, Kulnura, 6,291 ft.; 6, Kulnura, 6,293 ft.; 7, Muree sandstone, Congowai area; 8, Muree tillite, W. Maitland; 9, Branxton sandstone, Rothbury Creek near Branxton; 10, 11, 12, sandstone from Ravensfield quarry; 13, Ravensfield sandstone from Rutherford sections; 14, average composition of Kulnura specimens; 15, average composition of Ravensfield specimens.)

This brings out one of the most important points in mineral correlation, the need of examining sufficient specimens to obtain a type or standard residue for each bed or formation in the district in which the investigation is being carried out.

With the idea of starting a standard residue type for the Kulnura grit and for the Ravensfield sandstone the mineral percentages for each were averaged and appear as numbers 14 and 15, respectively, in Figure 2. If these standard types had been averages of, say, 50 specimens each, instead of so few, they would then have provided an adequate basis for comparison and contrast. Also if more specimens of the Muree rock had been available, a type could have been established for it; and so on, till definite residue types were established for all the formations of the upper and lower Marines with which this investigation is concerned.

Unfortunately the heavy minerals were not examined from the entire core and much might have been done if the work had gone on hand in hand with the paleontological determinations. Not only this, but the field is a new one (as yet unproved) and the results would have laid the foundations for future mineralogical investigations in this district. Only the last 30 feet of core were examined, and the task of correlation was made difficult because so few specimens of the upper Marine sediments were available for comparison; and these specimens were all collected at places from 12 to 40 miles away from the bore site. There are few records of successful correlation of beds over such distances.

Lateral variation is the difficulty, and it is of the greatest importance in correlation purposes, for in few areas near a bore site will it be possible to examine the entire series of sediments through which the bore passes. Comparisons must be made with formations cropping out some distance away.

## DISCUSSION

A considerable amount of work on the mineralogy of the Narrabeen and upper Marine series has already been done by Miss A. G. Culey (3, 4) and she records, with few exceptions, the same suite of minerals as that listed here.

The occurrence of this same suite of heavy minerals in the Narrabeen (Triassic) series in the upper Marine, and in the lower Marine Ravensfield sandstone, as well as in the Kulnura grit (probably upper Marine), points to the fact that for the period during which sedimentation was taking place, there was one distributive province which contained (A), an old sedimentary series, and (B) granites or other

acid igneous rocks. According to Walkom (10) the shore line in lower Marine times was many miles west of where it is now. Rivers drained the highlands on the west and brought down the material for these sediments. The presence of garnet is the chief mineralogical difference between the formations of the Hunter River Valley (Ravensfield sandstone, Branxton sandstone, and Muree tillite) and the Kulnura grit and Muree sandstone (at Congowai).

Garnetiferous rocks occur to the north-northwest of Newcastle (1). Therefore it is not surprising that the sediments laid down nearer the source of this mineral contain it. Garnet failed to reach the present position of Congowai or of Kulnura, which it must be remembered (Fig. 1) is at least 30 miles south of the garnet-bearing sandstones (Ravensfield and Branxton). In upper Marine time the sea extended as a wide gulf up past the position of the Serpentine Belt, the edge of which was in some places part of the shore line, therefore it is to be expected that the mineralogy of the Muree beds differs from north to south.

There should be a marked change in mineralogy when the ultra-basic rocks first became contributors to sedimentation, which, since they were injected towards the close of the Carboniferous (6, p. 63), might well be in the lowest beds of the Permian, for instance the Lochinvar shales (see Introduction).

On looking at Fig. 2 it is seen that there are mineralogical differences between the rock types. But owing to the few specimens examined no correlations can at present be made. Nevertheless it can be confidently said that the Kulnura grit more closely resembles, mineralogically, the Muree sandstone and tillite, than it does the Ravensfield and Branxton sandstones. Taking all the available information, the lithology, the heavy-mineral suites, the grain-size, and the presence of brachiopods, it seems valid to conclude that the Kulnura grit is part of the upper Marine series, probably the Muree stage. The Kulnura grit is a coarse rock like the Muree tillite; it is not fine-grained or clayey like the Ravensfield and Branxton sandstones. The amounts of zircon and tourmaline are quite different in the Kulnura and the Ravensfield. Titanite, anatase, and rutile are much more plentiful in the Ravensfield sandstone than in the Kulnura grit. It is perhaps unwise to draw conclusions from so few specimens, but the evidence seems to show the upper Marine character of the Kulnura grit. There is, however, one point which must be considered.

The Kulnura rock is coarse-grained, the Ravensfield and Branxton sandstones are fine-grained. The finer the sediment, within the fine sand and silt grades (but not the clay grade), the more likely it is to

contain heavy minerals. Therefore, how much of the difference in mineralogy is due to difference in type of sediment, and how much is due to differences in provenance? That the same rocks contributed to sedimentation is shown by the presence of the same suite of minerals, even down to the same varieties of these minerals in some instances.

## CONCLUSIONS

The heavy minerals of some of the Permian sediments from the Hunter River District were examined in detail because it was thought that they might provide a means of correlating beds cut by the drill with those outcropping in other parts of the area. The results of this investigation are inconclusive because insufficient specimens were made available. The mineralogy of the Ravensfield sandstone and of the Muree beds is placed on record, as this has not previously been described.

This investigation shows the following results.

1. In an area of continuous sedimentation with very little variety of source rocks, and one in which the same source rocks have contributed to the formation of earlier sediments there is little possibility that mineralogy will prove of much assistance in correlating one bed with another. Throughout all the specimens of Triassic, upper Coal measures, upper Marine, and other rocks examined here or by others (3, 4) the same fundamental suite of minerals is found. That there are local variations which may be helpful in future problems of correlation in the area is shown by the presence of garnet in some rocks and its absence in others.

2. If heavy minerals are to succeed when fossils are absent it is necessary to examine a large number of specimens of all the sedimentary rocks likely to be passed through in any bore in the district. This is especially necessary in districts where the mineralogy of the sediments is not at all well known.

3. The most promising lines for further mineralogical investigations with a view to establishing correlations of beds in the Permian of the Hunter River area seem to be the following.

A. The difference in grain-size of the mineral suites
B. A detailed survey of the varietal features of certain minerals, that is, zircon, tourmaline, and their distribution
C. A study of the distribution of such minerals as garnet and picotite
D. The examination of a great many more specimens from the various formations so that mineralogical types can be established
E. The possible mineralogical differences to be anticipated in the tuffaceous beds

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# PETROLOGY OF WHITTIER CONGLOMERATES, SOUTHERN CALIFORNIA[1]

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## ABSTRACT

The western part of the Puente Hills of Los Angeles County, California, consists of a series of Miocene and Pliocene shales with interbedded conglomerate and sandstone lenses. This paper presents the result of a petrologic study of the conglomerates. The prominent and important rocks are described in detail, and an effort is made to correlate these rocks with bed-rock types. The implications of these findings, such as the possible source area of the conglomerates and their paleogeographic significance, are briefly discussed.

## INTRODUCTION

*Location of area.*—The western Puente Hills are a low range (highest point, Workman Hill; elevation, 1,391 feet), having a general northwest-southeast trend, and bordering the coastal plain northeast of the town of Whittier in Los Angeles County. They are terminated on the northwest by the Narrows of the San Gabriel River. The conglomerates discussed are from Workman Hill and the western part of the hills between Turnbull Canyon and San Jose Creek (Fig. 1).

*Previous work.*—Much geological work has been done in this area (Eldridge and Arnold, 1907; English, 1926). More recently Max L. Krueger (1936) has published an abstract on the geology. However, very little attention has been given to the conglomerates. Only one report has been made on them (Edwards, 1934). The report includes descriptions of the Whittier conglomerates as well as those of Garfield Avenue in the Repetto Hills west of San Gabriel Narrows, and elsewhere, and purports to indicate the sources of the pebbles.

*Basis of this report.*—The work here reported was done at intervals during the years 1935–38. It was chiefly the collection, description, and tabulation of about 550 pebbles from five localities in five different beds of the Whittier conglomerates. Smaller collections were also studied but not included in the tabulations. In addition many pebbles were collected at random to check the reliability of the percentages and also to seek unusual diagnostic specimens. About 20 thin sections of the important rocks in this collection were studied. Two hundred and thirty pebbles from the Garfield Avenue Pliocene of the Repetto Hills, and small collections from the Miocene of the San Jose Hills on the northeast were also studied. From the possible source areas,

[1] Manuscript received, June 19, 1939.

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three collections of 100 pebbles each were obtained from San Antonio Wash and San Gabriel Canyon to represent the San Gabriel Mountains and from Silverado Canyon in the Santa Ana Mountains. In addition, random specimens from these and other areas were studied. Also about 20 thin sections were made of rocks in these collections from the source areas. In addition many other specimens and sections of bed rock from possible source areas were available at Pomona College.

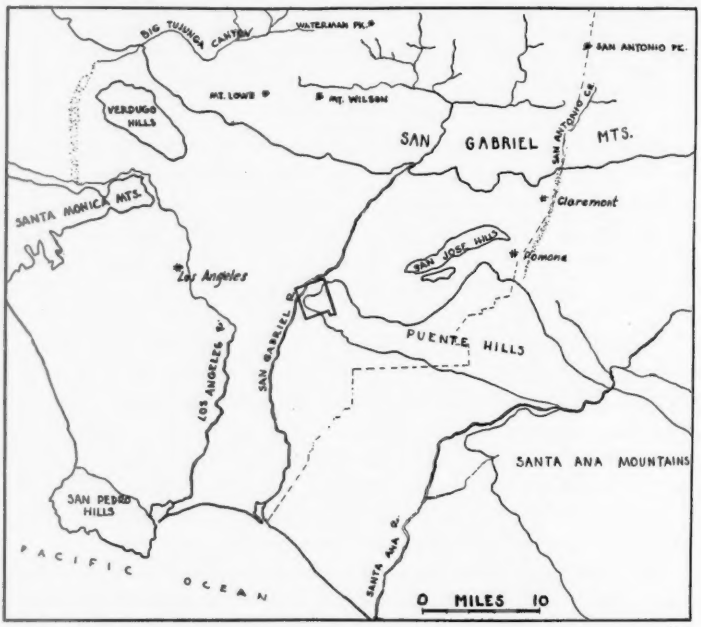


FIG. 1.—Index map of Los Angeles Basin and adjacent areas. Small square in center is area shown in detail in Figure 2.

The method of preparation and study of the conglomerates was the same in all cases. A typical part of the bed was selected, then sampled from a small area, usually not more than 3 feet square. The samples were screened, and all pebbles saved which were more than $\frac{1}{4}$ inch (6 mm.) in diameter, though only the pebbles more than $\frac{5}{8}$ inch (15 mm.) minimum diameter were studied extensively. The larger pebbles were broken open to present a clean, fresh surface for hand-lens examination.

*Stratigraphy and lithology.*—The rocks of the Puente Hills are

northwest-dipping sediments which have been divided into the Repetto formation (Pliocene) and the Puente formation (Miocene). The greater part of these sediments is soft light-colored shale, but sandy beds, conglomerate lenses, marl, and thin layers of porcellaneous shale are common.

The Miocene-Pliocene contact was placed by Eldridge and Arnold at about the middle of the north slope of Turnbull Canyon at the base of the lowest conglomerate to be considered in this paper. W. A. English also places the contact at the same horizon. The sediments south of this contact are known as the Puente formation, of middle and upper Miocene age. North of the contact the sediments have been considered Pliocene and called Repetto. More recent work indicates that the Miocene-Pliocene contact may be higher in the section, possibly as far as the north ridge in Sycamore Canyon.[3] The sediments between the contact in Sycamore Canyon and the one in Turnbull Canyon have been given a new formation name by Max L. Krueger and called the Sycamore formation (Krueger, 1936, p. 1520). The division is based on foraminiferal work. Lithologically the Sycamore and Repetto formations are practically identical, and the unconformity between them is slight.

A 5,350-foot stratigraphic section of the Repetto ("Fernando") in the area studied for this report is given by W. A. English (1926, p. 40). About half of this section is siltstone and shale and the rest (2,600 feet) is conglomerate and sandstone. Some of the comglomerate is very sandy and about 950 feet is pure sandstone.

The shales are grayish buff in color, consisting mostly of finely divided material which is in places calcareous. Fossils are rare, occurring in small patches and poorly preserved; here and there a fragment of whale bone is found. The foraminifera are in fairly good condition and are the only reliable markers.

The conglomerates are the next most abundant sediments. They occur as lenses in the shale, hundreds of feet thick but generally cropping out for less than a mile along the strike. They differ in character somewhat. Some show excellent bedding; others are poorly bedded and unsorted, very much like fanglomerates. The pebbles are only moderately well cemented in the sandy matrix and could be broken out with a geologist's pick. At only one place did the pebbles break with the matrix.

*Nomenclature of conglomerate beds.*—Since there are five beds of conglomerate discussed in this report each bed is named. Each name indicates as far as possible the locality of the bed (Fig. 2). The con-

[3] Oral communication from Richard Ten Eyck.

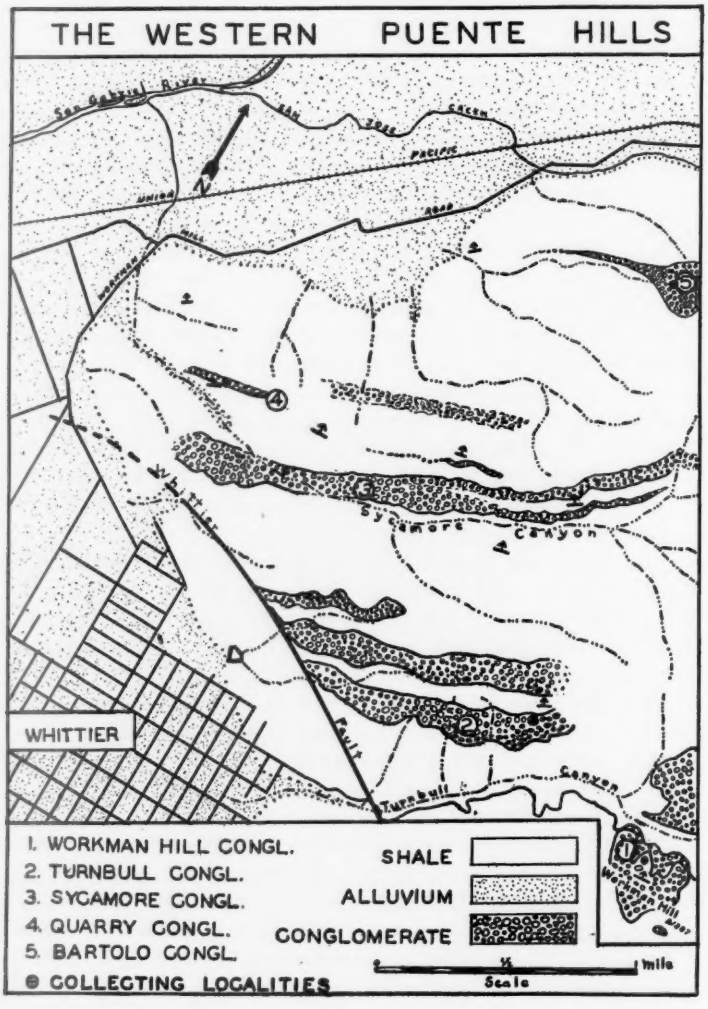


FIG. 2.—Geological map of western extremity of Puente Hills. El Monte and Whittier quadrangles of U. S. Geological Survey were used as base map. Most of geology was mapped by Pomona College field geology class in summer of 1933. Several small faults approximately at right angles to strike are not shown. Whittier fault is taken from English's map (1926, Pl. I).

glomerate which crops out on the same ridge and adjacent to Workman Hill was named the Workman Hill conglomerate. The lower bed cropping out on the north slope of Turnbull Canyon was named Turnbull conglomerate; likewise the Sycamore conglomerate is the lower bed in Sycamore Canyon. The Quarry conglomerate is also in Sycamore Canyon, its name being derived from the fact that a quarry and rock-crusher are in the middle of the bed. The Bartolo conglomerate crops out in a small, nameless canyon in the northern section of the hills, due east of Bartolo station on the Union Pacific R.R. Collectively these conglomerate beds (and other conglomerates in that section of the hills not specifically mentioned in this report) are known as the Whittier conglomerates.

### Workman Hill Conglomerate

*Field description.*—The Workman Hill conglomerate crops out approximately parallel with the Turnbull Canyon road. The strike is about N. 70° E. with a dip of 25°–30° NW. The bedding is very well defined and in a few places a thin layer of banded shale or a thin layer of sand, 6 inches thick and 5 feet or more long is found (Fig. 3). The material is sufficiently cemented to stand in vertical cuts more than 15 feet high, but weak enough so that samples can easily be obtained.

The collection was made at the side of the road about ½ mile southwest of the summit. The pebbles were dug out of the cut from an area less than 2 feet square. The shape of the pebbles ranges from rounded to subangular. Their size ranges from a foot long to less than one inch in diameter; probably the most common size is 2 inches. About one half the total material is more than ⅝ inch in diameter.

*Petrologic description. Plutonic.*—58 pebbles, 41 per cent.

21 specimens of biotite granite of distinctive type (hereafter called the "Conglomerate granite"): medium-grained granitic texture; composed of quartz, orthoclase, a little plagioclase, biotite, and muscovite (and chlorite up to 5 per cent)

11 specimens of granite pegmatite, including some rather doubtfully pegmatitic in texture: mineral grains up to ½ inch by 1½ inches; principal minerals quartz, microcline, orthoclase, a little plagioclase, muscovite, and biotite. Ordinarily either muscovite or biotite present, some of the biotite altered to chlorite. Specimens coarse and break along the cleavages of the feldspars; the cleavage faces commonly covered with minute flakes of muscovite

11 specimens of granite (?) aplite: white even-granular rock; largest grains, 1 mm.; contains quartz, orthoclase, plagioclase, and muscovite; in two specimens also a few small euhedral garnets

2 specimens of quartz monzonite (?): fine-grained granitic texture; contains quartz, orthoclase, plagioclase, and no dark minerals

2 specimens of granodiorite (?): light gray, medium-granitic texture, contains plagioclase, orthoclase, a little quartz, and small clumps of ragged biotite

7 specimens of other granitic rocks: texture fine or medium-grained; all containing quartz, orthoclase, biotite; two probably with small amounts of plagioclase; two specimens rather dark-colored, about one-third ferromagnesian minerals

2 specimens of quartz: pure quartz pebbles 1×¼×½ inches and 2×½×1¾ inches
2 specimens of slightly gneissoid granitic rocks, containing quartz, weathered feldspar and biotite

*Volcanic.*—30 pebbles, 20 per cent.

5 specimens of dacite: gray, porphyritic texture, phenocrysts of quartz, weathered feldspar (plagioclase) and biotite, with microcrystalline groundmass. The rock is a dacite similar to the mass found in the San Jose Hills at Mt. Meadows Country Club

FIG. 3.—Workman Hill conglomerate. Turnbull Canyon road, about ½ mile from summit. Shows interbedded conglomerate and sandy shale. Scale is shown by geologist's pick.

8 specimens of dacite (?): light gray, porphyritic, phenocrysts of quartz, plagioclase, and few flakes of biotite, with microcrystalline groundmass. Two of the specimens are weathered
2 specimens of basalt (?): dark brown; porphyritic; phenocrysts of weathered feldspar, probably plagioclase; groundmass containing many fine laths of plagioclase in a better state of preservation, no other minerals distinguishable
1 specimen of basalt (?): light gray, texture almost diabasic, numerous laths of plagioclase, groundmass weathered to clay with black speck of magnetite
14 specimens: undifferentiated volcanics, all very fine-grained or microcrystalline and weathered to some degree

*Metamorphic.*—55 pebbles, 39 per cent.

30 specimens of biotite gneiss: gneissic texture; bands ranging in thickness from 1½ cm. to the banding of schist. The dark minerals (mostly biotite) very prominent, their percentage ranging from 10 to 50 per cent. Minerals present: quartz, dominant feldspar orthoclase, commonly as porphyroblasts; plagioclase, probably in all samples present in small quantities; biotite probably averaging 30 per cent, not well preserved in all samples, ordinarily weathered light brown.

Rarer minerals: muscovite, more rarely epidote and chlorite. Limonite common as a weathering product

4 specimens of biotite schist: schistose texture, no banding visible, merely a general alignment of biotite flakes. Composition the same as that of the gneiss, with the average biotite percentage about 35 per cent. These specimens probably micaceous parts of the gneisses broken off during transportation

8 specimens of lenticular gneiss: lenticular gneissic texture. Minerals: quartz, orthoclase, plagioclase, weathered biotite, and chlorite. Two specimens have feldspars weathered and all the ferromagnesian minerals altered to limonite

1 specimen of quartz schist: banded texture, fine bands (1 mm.). Specimen consists almost entirely of quartz, with some feldspar and limonite

4 specimens of "dappled diorite" (?): texture irregularly banded, the light minerals almost aplitic while the ferromagnesian minerals occur in patches. Minerals: quartz, orthoclase (no plagioclase seems to be present), biotite, and some epidote

8 specimens: various metamorphic types, three gneissic and composed of quartz, feldspar and biotite, four of indefinite texture and composed mostly of quartz, and one of reticulated texture and composed mostly of dark green amphibole

ROCK PERCENTAGES

| | *Percentage* |
|---|---|
| "Conglomerate granite" | 14 |
| Granodiorite | 3 |
| Pegmatite | 8 |
| Aplite | 8 |
| Other plutonic rocks | 7 |
| Dacite | 3 |
| Other volcanic rocks | 17 |
| Biotite gneiss | 21 |
| Other metamorphic rocks | 18 |
| Quartz | 1 |

The Workman Hill conglomerate just described is typical of the conglomerate in the Whittier Hills and therefore it was described in some detail. The other conglomerates in this area will be described more briefly.

## TURNBULL CONGLOMERATE

*Field description.*—The collection of the Turnbull conglomerate pebbles was made on the north slope of Turnbull Canyon in the lowest conglomerate bed (stratigraphically) (Fig. 2). The bed is very sandy, more so than any of the others studied. Most of the sandy matrix is coarse. The bedding is very rough, similar to that of a fanglomerate. No cross-bedding was noticed but the pebbles are not uniformly distributed. Because of the firm cementation this collection was a little more difficult to obtain than the others. A weathered place was chosen and exactly one hundred pebbles were studied in the field with the aid of a lens.

Workman Hill may be separated from this and the following conglomerates by a fault striking NW.–SE.; therefore, the Workman Hill conglomerate may be equivalent to the Turnbull Canyon conglomerate.

ROCK PERCENTAGES

| | *Percentage* |
|---|---|
| "Conglomerate granite" | 19 |
| Pegmatite | 8 |
| Aplite | 4 |
| Dacite | 3 |
| Volcanic | 40 |
| Other metamorphic and plutonic | 7 |
| Biotite gneiss | 7 |
| Gneiss (other types) | 12 |

The high percentage of volcanic rocks in the list may be partially explained by the fact that the metamorphics and plutonics were more decomposed than the volcanics. Many of the biotite gneisses and granites were so badly weathered that they could be crumbled by hand. In collecting pebbles weathered out of the bed, the decomposed fragments do not persist as pebbles but break down readily to sand. This process increased the percentage of volcanics, particularly at the expense of the biotite gneisses.

### SYCAMORE CONGLOMERATE

*Field description.*—The Sycamore conglomerate is one of the largest single conglomerate beds in the Puente Hills. It is approximately 1½ miles long and about 600 feet thick. The average strike is N. 60° E. and the average dip is 45° NW. Toward the east the bed is divided into two members by a lens of siltstone.

Most of the pebbles are small, 1 inch or less in diameter. They are subangular to rounded; locally many of the little pebbles are almost as round as marbles.

ROCK PERCENTAGES

| | *Percentage* |
|---|---|
| "Conglomerate granite" | 22 |
| Granodiorite | 8 |
| Pegmatite | 3 |
| Aplite | 4 |
| Other plutonic rocks | 18 |
| Dacite | 4 |
| Other volcanic rocks | 14 |
| Biotite gneiss | 22 |
| Augen gneiss | 4 |
| Quartz | 1 |

### QUARRY CONGLOMERATE

*Field description.*—The Quarry conglomerate is of very small areal extent, cropping out only in Sycamore Canyon. It is a small lens which ends abruptly to the northeast and does not crop out on the south side of Sycamore Canyon. The length is about 800 feet, the average strike is N. 75° E., and the average dip is 50° NW. (Fig. 2). It is named from an abandoned quarry on the north side of the Sycamore Canyon road.

The specimens of this conglomerate, studied for this report, were collected on the south side of the quarry about three quarters of the way up the slope on the east side of the entrance. The area from which they were taken was not more than 3 square feet. At this point the conglomerate was loosely cemented and very easily collected. Some sections of this bed are very well cemented, so well that some of the rocks break with the matrix.

ROCK PERCENTAGES

| | *Percentage* |
|---|---|
| "Conglomerate granite" | 35 |
| Granodiorite | 3 |
| Anorthosite | 2 |
| Pegmatite | 1 |
| Aplite | 3 |
| Other plutonic rocks | 15 |
| Dacite | 6 |
| Dacite (?) | 5 |
| Other volcanic rocks | 9 |
| Biotite gneiss | 17 |
| Other metamorphic rocks | 4 |

"Biotite gneiss," in the foregoing table, includes a few specimens of lenticular gneiss. This does not apply to the other lists.

A granitic type studied by means of a thin section was anorthosite. This is a rare rock. The texture is closer to xenomorphic than any other specific texture. The edges of the grains have a peculiar granulated appearance; the interstitial parts are filled with granules (Fig. 4, F). This peculiar texture suggests crushing and partial recrystallization. Plagioclase of composition $Ab_{68}$ $An_{32}$ (andesine) makes up about 97 per cent of the rock; the remainder is interstitial mosaic, consisting of plagioclase, quartz and muscovite. Inclusions of apatite (?) are present in the andesine.

For the purpose of checking the distribution of types with relation to size a brief study was made of the smaller pebbles. A rough genetic classification of some of the pebbles smaller than 1 inch in diameter reveals the fact that the various types are present in the same relative abundance as the larger rocks.

| | *Specimens More than 1 Inch* | *Specimens Less than 1 Inch* |
|---|---|---|
| Plutonic | 74 | 72 |
| Volcanic | 41 | 38 |
| Metamorphic | 32 | 34 |

A more specific classification was also made and the results showed that the same rocks are present in about the same proportions. This would indicate that in this case no great error would be made by selecting only rocks over one inch in size for study.

### Bartolo Conglomerate

*Field description.*—The Bartolo conglomerate is stratigraphically the highest bed studied. It crops out on the south side of the most northerly canyon in the hills. Toward the west, the bed lenses out to merely a string of pebbles. The eastern extremity of the outcrop is not so clearly apparent but probably lenses out also.

The general attitude is the same as the other conglomerate beds studied. The bottom part of the bed is a hard reef of conglomerate very well cemented. The pebbles are scarce and when the rock is broken the pebbles always break with the rock. It is almost impossible to remove any of them from the matrix. Stratigraphically higher, the bed becomes more like the others in the degree of consolidation. In general, the pebbles are more smoothly rounded than they are in the other beds.

The samples were collected in two adjacent areas about a foot square and six feet apart near the center of the bed at the highest topographical outcrop.

Rock Percentages

| | *Percentage* |
|---|---|
| "Conglomerate granite" | 15 |
| Pegmatite | 10 |
| Aplite | 5 |
| Other plutonic rocks | 35 |
| Dacite | 3 |
| Other volcanic rocks | 4 |
| Biotite gneiss | 16 |
| Other metamorphic rocks | 7 |
| Quartz | 5 |

The only exceptional feature of this bed is the high percentage of quartz and pegmatite. The quartz is probably partly derived from pegmatites. The amount of pegmatite is so high that it is one of the most obvious rocks in the bed and gives the impression that its percentage is much greater than ten. Twenty-four of the 35 per cent of unclassified plutonics are gneissoid rocks. This group resembles the granites in the plutonic list both as to texture and composition.

### Important Rock Species of Whittier Conglomerate

The rocks most typical of the Whittier conglomerate assemblage are the "Conglomerate granite" and biotite gneisses, which together make up 37 per cent of the conglomerates. Thin sections of the granite were studied from the most important beds. The gneisses were studied with a hand lens only, because of their ordinarily poor state of preservation.

### "CONGLOMERATE GRANITE"

#### MEGASCOPIC CHARACTERS

The color of the "Conglomerate granite" is ordinarily gray. The rock is commonly iron-stained and partly weathered. The texture is medium-grained granitic. The average grain size is approximately 3 mm. and the largest grains are about 5 mm. (Fig. 4, A, B, C, D). The chief minerals are (in order of abundance) quartz and orthoclase, which appear to be present in about equal amounts, plagioclase, biotite, and muscovite. The micas differ a good deal; either biotite or muscovite may be present, or both. This granite has several facies; one with biotite dominant; a second, lighter, with muscovite dominant; a third, somewhat aplitic facies; a fourth, slightly gneissoid. A rare variety contains garnets (2 mm. diam.), ordinarily with muscovite as the only mica; this rock is not common, but occurs in most beds.

#### MICROSCOPIC CHARACTER (SUMMATION OF CHARACTERISTICS SEEN IN 9 SECTIONS)

The texture is essentially medium-grained granitic, but some of the feldspar grains are poikilitic and others micropegmatitic. Most of the feldspar grains are partly altered. The mineral composition is as follows:

*Quartz.*—Quartz constitutes approximately 20 per cent (average) of the "Conglomerate granite." The average grain size is about 2.3 mm. The shape is anhedral; some grains have ragged (resorbed ?) edges. Extinction is ordinarily undulatory, very marked in some cases. Many "strings" of inclusions are present, commonly rounded, resembling bubbles under high magnification, though some are angular and might be small mineral grains. Other inclusions are apatite and zircon.

*Orthoclase.*—Orthoclase makes up about 60 per cent (average). The large grains are slightly larger than the quartz, but the average are smaller (2.0 mm.), their shape subhedral. Poikilitic quartz is ordinarily present as round inclusions (0.3 mm. diameter). A few of the crystals are myrmekitic (Fig. 4, A, C). These are not found throughout the rock but occur in small patches. Some grains are completely myrmekitic and the intergrowth also affects the borders of the adjoining grains. Some of the orthoclase is sericitized. Some grains of microcline were seen.

*Plagioclase* (*oligoclase*).—Plagioclase constitutes approximately 10 per cent (average). The grain size maximum is nearly the same as for the orthoclase, but the average size is larger (2.4 mm.), and the shape

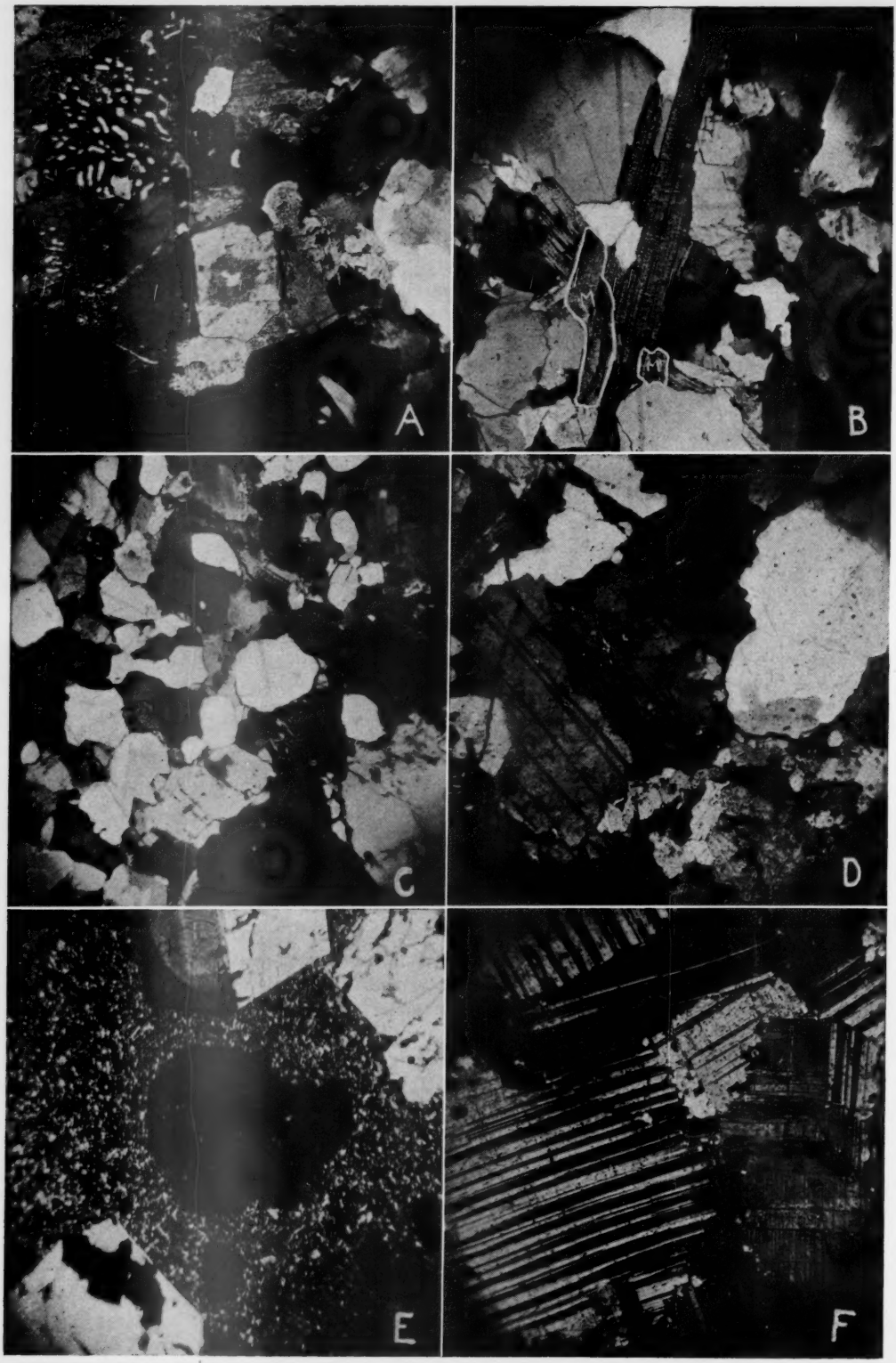


FIG. 4.—(See opposite page for explanation.)

subhedral. The composition ranges from $Ab_{85}An_{15}$ to $Ab_{75}An_{75}$. Obscure zoning was observed in only two crystals. Besides albite twinning there is also some pericline and Carlsbad present. Alteration is common, in some crystals selective, merely affecting one set of twin lamellae (Fig. 4, D).

*Biotite and muscovite.*—Either biotite or muscovite, or both, may be present. The two micas are treated as one mineral because of their mode of occurrence. The biotite was the primary mica, later partially replaced by muscovite, the evidence being biotite flakes surrounded by muscovite or half a crystal of biotite altered to muscovite (Fig. 4, B). The feldspars in some cases were also partially replaced. The range in crystal size is much greater than that of the other minerals, from 2.4 mm. to very small shreds. The biotite is in various stages of preservation ranging from quite fresh to almost completely altered to muscovite. The biotite pleochroism is marked, light brown to very dark brown. Inclusions are rare. The edges of the biotite commonly have encroaching muscovite flakes; all the rocks sectioned show both micas though careful examination may be required to detect them. This rock could be called either a two-mica granite or biotite granite according to A. Johannsen (1932, pp. 225–26). The name would depend on whether any of the muscovite was primary or not. Most of the muscovite in the biotite facies probably is secondary. However, as the muscovite in the light-colored garnet facies probably is primary, the rock could be called by either name.

### BIOTITE GNEISS

The biotite gneisses present a great diversity of texture, ranging from evenly banded to porphyroblastic or lenticular with or without augen. Maximum width of the bands is about 1.5 cm. as observed in the pebbles; however, some of the schistose specimens may be fragments of coarser gneiss. The gneisses are nearly all badly weathered and iron stained. The mineral content, estimated with a hand lens, is on the average perhaps 40 per cent orthoclase (or microcline), 35 per cent quartz, 10 per cent plagioclase, 10 per cent biotite, 5 per cent (or less) muscovite, chlorite, epidote, limonite. The potash feldspar occurs in small grains to large porphyroblasts 4×1 cm., either pink

FIG. 4.—Photomicrographs of pebbles from Whittier conglomerates, crossed nicols, magnification, 30×. A. "Conglomerate granite" showing myrmekite intergrowths of quartz and feldspar. B. "Conglomerate granite" showing intimate intergrowth of muscovite (*M*) and biotite. C. Aplite similar to "Conglomerate granite," showing aplitic texture and myrmekite. D. "Conglomerate granite," showing selective alteration of twin lamellae. E. Dacite showing zoning of feldspar and microcrystalline groundmass. F. Anorthosite, showing plagioclase with granulated edges.

or white, much of it weathered. The quartz is finer-grained and fractured, intermingled with the feldspar. The biotite is more prominent than its low percentage suggests, as it is ordinarily in 1 mm. flakes and aggregates. Many are weathered golden brown and some are partly chloritized. The exact amount of plagioclase is rather difficult to estimate; its grain size averages about 2 mm. The other minerals are of minor importance.

### DACITE

A number of pebbles of dacite were examined with a hand lens, and a few sections were studied microscopically. The rocks are light gray in color, flecked with euhedral brown biotite. The amounts of quartz and biotite phenocrysts seem to be variable while the plagioclase remains constant. Many specimens show very little quartz, as phenocrysts. The quartz phenocrysts average 3 mm. in size and are ordinarily embayed, rarely anhedral. The plagioclase is nearly all zoned (Fig. 4, E), some of it oscillatory, the range being oligoclase to andesine. The biotite is anhedral and some is weathered golden brown. Some sections cut across the cleavage present a braided appearance due to alteration (chloritization). The groundmass is microcrystalline.

### PEGMATITES AND APLITES

The pegmatites and aplites are white, though some of the feldspars are pink. A few small red garnets are present in some specimens, but no tourmalines or other rare minerals were noted. Muscovite is the most common mica associated with the pegmatites but a few specimens contain biotite. Five specimens of the pegmatite from the Workman Hill collection were studied in oils. They all contain microcline and four of them also have plagioclase, and some contain orthoclase also. The plagioclase is oligoclase ($Ab_{80}An_{20}$) with alpha approximately 1.540.

### GRANODIORITE (INCLUDING QUARTZ MONZONITE)

The differentiation of this rock from the granites is based on the relative amounts of orthoclase and plagioclase, though this proportion was not certainly determined in all samples. The granodiorites of the conglomerates are as light-colored as the granites and about the same texturally. Biotite is ordinarily the associated mineral. These rocks are not abundant and a few border-line cases may have been included with the granites.

### OTHER ROCKS

The "other rocks" in the summary table are too diversified to

permit brief description, only two or three specimens of most of the species being found. These other rocks include granites different from the "Conglomerate granite," granodiorite, quartz diorite, diorite, metamorphic rocks other than the biotite gneisses, volcanic rocks including basalt, and a large group of rocks which could not be identified, mostly because of weathering. Those considered important (such as the granodiorite and anorthosite) were a little more fully described in previous sections.

In scouting around the hills a number of other significant rocks were discovered. Evidently they occur in small amounts since they were not found in any of the collections. Of these rocks three are worth mentioning: coarsely crystallized limestone, quartzite, and an amphibole rock. The limestone is composed of coarse calcite of xenomorphic texture, individual cleavage faces being almost a half inch across. It bears a close resemblance to the Edison limestone of the Cascade Canyon region, near San Antonio Canyon in the San Gabriel Mountains, but could probably also be related to the crystalline limestones of the Crestmore-Colton region (south of the eastern end of the San Gabriel Mountains and about 40 miles east of the Whittier conglomerates). The quartzite is a dense, fine-grained rock. A petrographic examination revealed the presence of garnet. This rock also resembles the quartzite of the Cascade Canyon assemblage of interbedded limestone and quartzite. The amphibole rock is composed of very much altered (chloritized ?) amphibole with traces of limonite.

## Summary Table

The summary table is a summary presentation of the relative rock percentages in the various conglomerates. The average is not an average of the percentages on previous pages, but was obtained by considering all the collections as one assemblage of specimens. The exceptionally high percentage of granite in the Quarry conglomerate has slightly raised the average percentage of this rock. The quantities of the biotite gneiss and "Conglomerate granite" are probably more nearly equal than the chart indicates.

Summary Table

| | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| | | | *Percentage* | | | |
| "Conglomerate granite" | 14 | 19 | 22 | 35 | 15 | 21 |
| Pegmatite | 8 | 8 | 3 | 1 | 10 | 6 |
| Aplite | 8 | 4 | 4 | 3 | 5 | 5 |
| Dacite | 3 | 3 | 4 | 6 | 3 | 4 |
| Biotite gneiss | 21 | 7 | 22 | 17 | 16 | 16 |
| Other rocks | 46 | 59 | 45 | 38 | 51 | 48 |

1. Workman Hill conglomerate.
2. Turnbull conglomerate.
3. Sycamore conglomerate.
4. Quarry conglomerate.
5. Bartolo conglomerate.
6. Average of all localities.

## Sources of the Conglomerates

### Eastern source areas

According to the paleogeographic maps by R. D. Reed (1933, pp. 218 and 252) in upper Miocene and Pliocene time the land south and west of the Puente Hills was submerged. This leaves only the north and east as possible contributors to the Whittier conglomerates. The eastern area will be considered first. This includes the San Bernardino Mountains, the Perris Block and the Santa Ana Mountains.

Of these physiographic units the Perris Block is probably the most important. The original definition of this block is given by W. A. English (1926, Pl. 3). It is bounded on the northeast by the San Jacinto rift and on the southwest by the Elsinore graben, extends northward through the San Bernardino Valley to the base of the San Gabriel Mountains, beneath such towns as Chino, Claremont, and La Verne, and extending almost as far east as San Bernardino. The rocks in this region as described by Paul Dudley (1935, p. 487) in a small but typical area, do not resemble the conglomerates. Dudley's collection was available at Pomona College and comparisons with the conglomerate pebbles could readily be made. The rocks of the area are dominantly crystalline, consisting of a series of metamorphics, a porphyry, a group of plutonics, and some shales and clays of Eocene age. The metamorphic rocks are schists and gneisses, slates, granulites, and meta-volcanics. The schists and gneisses are probably the most important of this group. They have approximately the same minerals as the Whittier conglomerate gneisses but texturally are slightly different. Also, their colors are notably darker, ranging from dark brown to bluish black. The predominant plutonic rocks of the area range from granodiorite and quartz monzonite to gabbro. They are rich in plagioclase, ordinarily of oligoclase-andesine-labradorite composition. The ferromagnesian minerals present are biotite, hornblende, augite, and olivine. The resistant pegmatites of the Jurupa Mountains, in the northern part of the Perris Block, seem to be chiefly of the quartz-microcline-oligoclase type, with black tourmaline as a common accessory. The Temescal (Perris) dacite porphyry has a dark groundmass with pronounced euhedral plagioclase phenocrysts and no obvious biotite plates, quite different from those of the conglomerates, which have a light gray groundmass, with prominent biotite plates.

A more recent investigation of the Perris region (Osborn, 1939) indicates that the quartz monzonite of Dudley is, in part, biotite granite. Osborn's description shows that the granite facies of this rock mass resembles the granite of the Whittier conglomerates in

mineralogical composition. It may, however, be significant that the granite of the conglomerates does not show the dark, fine-grained inclusions which are at least locally abundant in the granite described by Osborn.

The Perris Block has been proposed by E. C. Edwards (1934) as the principal source of the Whittier conglomerates. The Workman Hill collection described in this report was made at the locality studied by Edwards. His description of the conglomerate pebbles is quite different from that in this report. In particular, he emphasized the abundance of pegmatites and aplites, which together made up 45 per cent of his count, and minimized the importance of biotite gneiss. Apparently the granite of this report (Fig. 4) was called aplite and pegmatite by Edwards.

### SAN BERNARDINO AND SANTA ANA RANGES

The regions on the northeast (San Bernardino Mountains and others) and on the southeast (Santa Ana Mountains) were also considered as possible sources. The San Bernardino Mountains contain plentiful biotite schists and gneisses and various plutonic rocks of which the Cactus granite is the most extensive. In the northern half of the range there are great masses of quartzite and crystalline limestone (Vaughan, 1922, Woodford and Harriss, 1928). One facies of the Cactus granite (Vaughan, 1922, p. 365) is very similar to the "Conglomerate granite." However, the absence of other typical San Bernardino rocks and especially the extreme rarity of quartzite pebbles in the conglomerates, make it improbable that the northern or central portions of the San Bernardino Mountains contributed to the Whittier sediments.

The detrital material in Silverado Canyon, which drains a typical part of the Santa Ana Mountains, was found to be very different from the conglomerate assemblage, especially in the abundance of calcareous sandstones and slaty rocks.

The whole eastern region from the San Bernardino Mountains to the Santa Ana Mountains has many different kinds of rocks, but only the fairly common and more resistant types might be expected to be found in the conglomerate. These are mostly igneous and metamorphic rocks. Most of the igneous rocks are rich in plagioclase with hornblende, augite, and even olivine as ferromagnesian minerals. They are different from the conglomerate rocks which are more felsic and very rarely contain any ferromagnesian minerals other than biotite.

Not one of the distinctive rocks of the region east of the Puente Hills has been found in the conglomerates in unmistakable examples,

and tourmaline pegmatite and typical Temescal dacite porphyry have not been found at all. Though the area may have contributed some detrital material to the Puente Hills upper Miocene and Pliocene sediments the evidence at hand does not justify the conclusion that it was the major contributor.

### NORTHERN SOURCE AREAS

As the eastern land mass has been considered, there remains only the area on the north, most of which is now known as the San Gabriel Mountains.

The San Gabriel Mountains northeast of Los Angeles are about 75 miles long and 20 miles wide (at the widest part), trending east and west. The greatest difficulty in correlating the conglomerates with the rocks in this range is the lack of exact geologic and petrographic knowledge of these mountains. Only about one-half to two-thirds of the range has been mapped, and not all of this work is precise. The unknown parts may contain some rocks not yet described from this area. In general, this range may be considered as a large fault block of igneous and metamorphic rocks bordered on all sides by Tertiary sediments and volcanics, and Quaternary fanglomerates. The main block is composed principally of fine and coarse schists, granitic gneisses, biotite granite, granodiorite, quartz monzonite, various basic porphyries, and some metamorphosed sediments, such as limestone and quartzite. The whole mass is complexly faulted and a large part of it is injected with pegmatites and aplites.

Gneiss is a characteristic rock of the San Gabriel Mountains, occurring in most parts of the range. Examples are briefly described by R. Arnold and A. M. Strong from the general region of Mt. Lowe (Arnold and Strong, 1905, p. 202). Another description of these gneisses is given by R. Eckis in a groundwater report (Eckis, 1934, p. 40).

> A series of well banded metamorphic gneisses occur in the San Gabriel Mountains, . . . [they] . . . form the main mass of the southern slopes of the mountains eastward from Dalton Canyon almost to Lytle Creek. West of Dalton Canyon these banded gneisses swing northerly into the heart of the range. Typically, they are alternating well defined light and dark bands from a few inches to more than a foot wide. Locally, the banding is thinner and the rocks are practically schists. The light bands are generally quartz, or quartz and feldspar; the dark bands are largely biotite (black mica) and hornblende, sometimes green chlorite.

In order to ascertain the quantity and character of these gneisses a collection of gravel was made in San Antonio Wash. The specimens were collected east of Claremont, in a rock crusher pit, on Sixth Street

about one mile east of College Avenue, and just east of the Los Angeles-San Bernardino County line. Seventy per cent of the rocks were metamorphics, the rest were dacite, granodiorite, basalt and quartz in order of abundance. The gneisses show various crystalloblastic textures such as lenticular banding, and porphyroblastic texture. The feldspar is predominantly potash feldspar, in places as large pink crystals. Quartz is nearly everywhere present. Plagioclase is present in some places in small amounts. The ferromagnesian constituents seem to be the principal variants. About one half of the specimens contain hornblende and the others have only biotite and muscovite. These two gneisses together make up approximately half of this sample of detrital material from San Antonio Canyon.

A biotite granite from the San Gabriel Mountains is described by Arnold and Strong, as a large mass with slightly varying facies cropping out in the region of Mt. Waterman (*op. cit.*, p. 189). A very good description is given of this granite.

> It is hypidiomorphic granular in texture and consists essentially of orthoclase and quartz although well developed crystals of plagioclase are not uncommon—biotite is found sparingly—a little muscovite is also present as a secondary product in some of the orthoclase.

Another variety richer in biotite is described as having microcline, also,

> Intergrowths of this mineral and quartz were [noted][possibly myrmekite]. The orthoclase and microcline together are in excess of the plagioclase. . . . One crystal of plagioclase shows every alternate albite twin completely kaolinized while the intervening ones are unaltered [This feature was noted in a thin section of the "Conglomerate granite"].

One facies had oligoclase; other plagioclase compositions were not given. Many specimens of this biotite granite are to be found in the West Fork of San Gabriel Canyon, and this suggests that the rock is more widely exposed than was indicated by Arnold and Strong. About 25 per cent of the gravel is biotite granite, not all similar in texture and appearance but perhaps facies variations of one igneous mass. A very little of this same granite can be found in the North Fork of the San Gabriel River. Six specimens of the West Fork material were sectioned and studied. The texture is granitic, some fine-grained and some coarse. Poikilitic quartz and micropegmatitic intergrowths of quartz and feldspar are common. The minerals present in order of abundance are orthoclase and microcline, quartz, plagioclase, biotite, and secondary muscovite. The quartz has numerous "strings" of inclusions. The plagioclase is oligoclase ($An_{18}$–$An_{25}$), commonly

partly altered to muscovite or sericite, and only in exceptional conditions is it zoned. The biotite has a marked pleochroism varying from light brown to a very dark brown, some with ragged edges and encroaching secondary muscovite. This rock is a duplicate of the Whittier "Conglomerate granite."

The other granite of the San Gabriel Mountains for which petrographic descriptions are available is the Echo granite (Miller, 1934, p. 12). Though it is somewhat similar, it is not the same as the "Conglomerate granite."

The pegmatites and aplites of the western San Gabriel Mountains are said by W. J. Miller (1934, pp. 47–48) to be granitic in composition. Texturally they grade from granitic to pegmatitic. Of the pegmatites Miller makes the statement, "Minerals other than potash feldspar, quartz and some muscovite seldom occur." An examination was made of some of the pegmatites in the San Gabriel foothills north of Claremont. Texturally the aplite and pegmatite grade into each other in the same dike and the composition is almost entirely quartz and pink orthoclase, with a little plagioclase. A clear case of correlation can not be established since pebbles of common pegmatites have a tendency to resemble each other, if no exotic minerals are present.

A rock which may be traced definitely to the San Gabriel Mountains is anorthosite. W. J. Miller (1931, p. 334) gives a very good description of this exceptional rock. The grain size is given as $\frac{1}{8}$–1/12 inch and the mineral content about 98 per cent plagioclase, ordinarily andesine. This rock is not common in southern California, its occurrence being restricted to the Tujunga region of the San Gabriel Mountains and adjacent areas. Therefore, it is safe to assume that the source of the anorthosite in the conglomerate was in the western part of the San Gabriel Mountains. This would extend the source area as far west as the Tujunga region in the western San Gabriel Mountains.

The plentiful pebbles, whose source can most definitely be established, are the dacites. A similar dacite (locally called the Mt. Meadows type) crops out in the eastern part of the San Jose Hills between the Puente Hills and the San Gabriel Mountains (Mull, 1934, p. 7). It has also been obtained from wells near La Verne and Claremont and occurs as dikes in the vicinity of San Antonio Canyon and elsewhere in the south-central San Gabriel Mountains. Also from a tabulation of 100 pebbles in the San Antonio Wash, 8 were dacite and at least 3 of these were of the Mt. Meadows type.

A petrographic comparison by thin section and literature (Mull 1934) shows the Mt. Meadows dacite to be the same as the conglom-

erate dacite. Texturally, they are identical and their mineralogical compositions also correspond even to the corroded quartz phenocrysts and zoned plagioclase. This correlation might extend the source area of the conglomerate as far east as Claremont and Pomona.

The fact that the several rocks just discussed can be traced back to the San Gabriel Mountains seems strong evidence that this northern block contributed to the conglomerate in the Puente Hills.

## Age of San Gabriel Mountains

The age of the San Gabriel Mountains has been a moot question among California geologists for a number of years. The consensus seems to be that at least an ancestral range was present during most of Tertiary time, the age of its first appearance being unknown, and that the last great uplift which raised the range to its present position occurred during Quaternary time.

The evidence that some material of the Whittier conglomerates of late Miocene and early Pliocene time is similar to that of the San Gabriel Mountains suggests the possibility of a highland of approximately the same composition and in the same general position as the present day San Gabriel Mountains as early as late Miocene. Later faulting raised it to its present position.

The fact that the assemblage in the conglomerates does not have the same proportion of rocks as would be found in a conglomerate derived from the present San Gabriel Mountains suggests that the rocks available for erosion in middle Tertiary time were present in proportions different from those occurring now. The principal differences are the rarity of plagioclase rocks in the conglomerates and the almost complete absence of hornblende-bearing rocks. The rocks eroded during Tertiary time may have been different from those exposed today and the higher zones, both igneous and metamorphic, may have been richer in biotite and poorer in hornblende. This is not unreasonable petrologically.

## Summary

The Whittier conglomerates, a series of Pliocene and Miocene conglomerate lenses in the northwest part of the Puente Hills, were studied to determine their petrologic character and their probable source or sources. The principal rocks found in the conglomerate were a distinctive granite (21 per cent), biotite gneiss (16 per cent), and in smaller quantities pegmatites, aplites, dacite, *et cetera*. The granite characteristic of these conglomerates is called the "Conglomerate granite." It has a typical granitic texture with myrmekitic inter-

growth of quartz and feldspar and contains quartz, orthoclase, microcline, plagioclase, biotite, and secondary muscovite. The biotite gneisses have varied textures from lenticular to banded and contain quartz, orthoclase, and biotite as principal minerals. The rocks of the conglomerate assemblage are typically felsic; moreover, plagioclase is not plentiful and hornblende is very rarely found.

The possible source areas for the conglomerate are either on the north or the east. The eastern area and especially the extensive Perris Block, consists mostly of igneous rocks rich in plagioclase and with abundant hornblende, as well as biotite. Metamorphic rocks are also present, but are not so common as the igneous rocks. In particular, quartz-orthoclase-biotite gneiss is relatively rare. The northern area, the San Gabriel Mountains, is composed almost entirely of igneous and metamorphic rocks. The igneous rocks are granites, quartz monzonites, granodiorites, quartz diorites, *et cetera*. The "Conglomerate granite" is identical with a granite from the Mt. Waterman region in the San Gabriel Mountains. A dacite and an anorthosite can also be correlated with rocks in the San Gabriel Mountains, and the biotite gneisses are very similar. On the basis of these few rock correlations, a general similarity to the San Gabriel Mountains, and a dissimilarity to the Perris Block region, it is concluded that the San Gabriel Mountains are an important source of the Whittier conglomerates, and may be the principal source. This hypothesis implies the existence of a mountain mass of approximately the same composition and about in the same place as the present San Gabriel Mountains during late Miocene and early Pliocene time.

Since the sources for the greater part of the conglomerate pebbles have not been determined, it may be that many of the pebbles were derived from the relatively unstudied area, which reaches from the eastern San Gabriel range across the San Bernardino basin to the southern San Bernardino Mountains.

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# PALEOZOIC AND PRE-CAMBRIAN ROCKS OF VANCE WELL, DELAWARE COUNTY, OHIO[1]

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Columbus, Ohio

## ABSTRACT

The Vance well brings out several points of interest. It adds to the known extension of basement rocks of igneous origin to central Ohio. In this well such rocks were largely gneiss and are comparable with similar deposits in large fields on the north in Canada. From this and other wells in western Ohio it is apparent that the surface of these crystalline deposits represents an old erosion surface with much local and regional relief. Next the Cambrian rocks of sedimentary origin are worthy of note both for the number and the thickness of sandstone strata and for the high content of sandy material in the dolomite components. In the Vance test the St. Peter sand was not detected by analysis but the unconformity between the Black River and the Lower Magnesian groups was definitely marked by the abrupt change from limestone to dolomite. The brine at this horizon was decidedly weak but was comparable with others throughout western Ohio. The evidence shows clearly that the green shales at the unconformities and those within the formations are simply normal deposits and have no relation to bentonite. The chief coloring pigment is celadonite, a glauconitic mineral, derived through chemical changes from muscovite, and present through a wide range of the geological column.

## INTRODUCTION

The Herman E. Vance well No. 1 was located on Lot 11, Sec. 3, Orange Township, Delaware County, Ohio, on the bluff east of the Olentangy River, about 10 miles south of Delaware and 14 miles north of Columbus. The test was financed by Chester L. Wise and others of Washington, Pennsylvania. The contractor was Samuel D. McCloy of Washington, Pennsylvania, and the drillers responsible for most of the hole were Benjamin Eschbacker and Carl Sutton of Steubenville, Ohio. The rig was built in August and drilling began on September 3, 1934. After the Trenton was reached, drilling was done on a day shift of 8 hours each. The well was finally completed on May 15, 1937, at a depth of 4,291 feet, thus penetrating the strata from the basal portion of the Ohio shale of Devonian age to and into the crystalline rocks of pre-Cambrian age. The elevation of the well-head was 920 feet.

Through the kindness of the contractor and the drillers, a fine set of samples was saved for inspection and testing. These were taken from 5 to 25 feet apart and carefully labeled as to depth.

The description of the Paleozoic rocks has been prepared by the senior writer, whereas the description of the pre-Cambrian rocks has

[1] Manuscript received, August 22, 1939.

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[3] Ohio State University.

been prepared by the junior writer. The rocks of the Paleozoic section of the well are described first.

## Paleozoic Section

### Application of Chemistry to Correlation

In order to determine the character of the rock penetrated by the drill, samples of the cuttings were given a rough analysis by the Geological Survey of Ohio. The procedure was to treat the sample with weak acid and then digest on the hot plate for 20 minutes. The insoluble residue was then filtered off, dried, and weighed. Such residues consisted of either fine shaly or silty materials or of sand, either fine or coarse. Next the lime, $CaO$, was accurately determined by precipitation, filtration and titration. The lime, $CaO$, thus found was calculated to calcium carbonate, $CaCO_3$. The sum of the insoluble residue and the calcium carbonate was then subtracted from 100 per cent, the difference being considered mainly as magnesium carbonate, $MgCO_3$. This assumption, however, is in considerable error due to the presence of iron oxides, phosphorous pentoxide, manganese oxide, organic matter, *et cetera*, also present in the rock.

The analytical work, however, gives a very good clue to the nature of the rock, whether dolomite, limestone, sandstone, or shale. Likewise, in some cases, through a sharp change in composition, it shows definitely the division of one formation from another.

## Brines

In the Vance well the casing was set at the following depths.

| *Size of Casing* | *Depth in Feet* |
|---|---|
| 10 -inch | 30 |
| 8 -inch | 830 |
| 6½-inch | 2,782 |

The drillers reported water or brines as here given.

Small flow at 100 feet, fresh water
Large flow at 280 feet, sulphur water (at horizon of Oriskany sand)
Brine at 2,738–2,760 feet, hole full (this brine was in dolomite below St. Peter and was sampled for analysis)
Water sand and gas bubbles at 3,450–3,455 feet (this in sand and concentrated brine)
Water sand at 3,775–3,786 feet
Water sand and big dose of brine and gas bubbles at 3,820–3,825 feet (this brine was in sand directly above crystalline rocks and was sampled when drill was at depth of 3,860 feet)

The brine in the dolomite not far below the St. Peter horizon, or at a depth of 2,738–2,760 feet, was analyzed by the Survey with the following results.

Analyst, Downs Schaaf
Specific gravity, 1.05 at 15° C.
Mineral sediment, none

| | *Percentage* |
|---|---|
| *Cl* | 61.86 |
| *Br* | 0.38 |
| $SO_4$ | 0.70* |
| $CO_3$ | 0.03 |
| $HCO_3$ | 0.07 |
| *Na* | 26.59 |
| *K* | 0.55 |
| *Ca* | 6.15 |
| *Sr* | 0.28 |
| *Mg* | 3.29 |
| $(Al, Fe)_2O_3$ | 0.06 |
| $SiO_2$ | 0.04 |
| | 100.00 |

Total dissolved solids, 71.5 grams per kilogram

* Sample as received contained 60 parts per million of $H_2S$.

This brine is thus very weak for the depth, for normally such a brine should contain about 230 parts per kilogram instead of 71.5 parts. Five other samples from the St. Peter horizon throughout western Ohio show 35, 38, 41, 42, and 46 parts per thousand which closely approximates that of sea water with 37 parts per thousand. Evidently this disconformity was sufficiently open to allow fresh water to penetrate far down the slope.

The brine taken at the depth of 3,860 feet but evidently coming mainly from 3,820–3,825 feet is more concentrated.

Analyst, Downs Schaaf
Specific gravity, 1.15 at 15° C.

| | *Percentage* |
|---|---|
| *Cl* | 61.96 |
| *Br* | 0.33 |
| $SO_4$ | 0.27 |
| $CO_3$ | none |
| $HCO_3$ | 0.01 |
| $H_2S$ | none |
| *Na* | 21.97 |
| *K* | 0.83 |
| *Ca* | 12.24 |
| *Sr* | 0.50 |
| *Mg* | 1.83 |
| $(Al, Fe)_2O_3$ | 0.04 |
| $SiO_2$ | 0.02 |
| | 100.00 |

Total dissolved solids, 180 grams per kilogram.

Although concentrated, this brine is yet weaker than normal for the depth. These lower brines are radioactive but the exact cause of this has not been determined.

## Section of Vance Well

| System | Series or Group | Formation | Description of material | Analysis: Insoluble Residue | Analysis: $CaCO_3$ | Analysis: $MgCO_3$ and others | Thickness | Top | Bottom | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|
| Devonian | | Ohio | Shale, brown to black, fissile | ---- | ---- | ---- | 125 | 0 | 125 | |
| | | Olentangy | Shale, grey, soft, calcareous | ---- | ---- | ---- | 24 | 126 | 150 | |
| | | Delaware | Limestone, dark, hard, thin to medium bedded | ---- | ---- | ---- | 38 | 150 | 188 | |
| | | Columbus | Limestone, light, hard, medium to massive bedded | ---- | ---- | ---- | 92 | 188 | 280 | Base of Columbus locally siliceous |
| | | Oriskany | Sandstone, wanting | ---- | ---- | ---- | 0 | 280 | 280 | Large flow of water |
| Silurian | Monroe | | Dolomite, hard, dark grey, thin bedded | ---- | ---- | ---- | 240 | 280 | 520 | Much alike throughout the whole thickness |
| | | | Dolomite, hard, dark grey to brown, thinbedded | 3.8 | 54.5 | 41.7 | 130 | 520 | 650 | |
| | | | Dolomite, hard, dark grey to brown, thin bedded | 7.8 | 52.2 | 40.0 | 40 | 650 | 690 | |
| | Niagara | | Dolomite, massive, grey, soft | 4.7 | 55.3 | 40.0 | 60 | 690 | 750 | Newburg sand Top |
| | | | Dolomite, bluish grey, massive, medium hard | 5.2 | 55.4 | 39.4 | 80 | 750 | 830 | of Niagara dolomite |
| | Clinton | Alger | Shale, calcareous, light to mottled, some dolomite | 37.1 | 35.3 | 27.6 | 50 | 830 | 880 | Rochester of New York section |
| | | Dayton | Dolomite, with some calcareous shale | 13.0 | 48.6 | 38.4 | 25 | 880 | 905 | "Little Lime" or |
| | | | Shale, calcareous with some dolomite | 59.3 | 24.0 | 16.7 | 35 | 905 | 940 | "Shell" of driller |
| | | Brassfield | Dolomite, limy, with some calcareous shale | 51.2 | 39.8 | 29.0 | 40 | 940 | 980 | |
| | | | Shale, calcareous, with some limestone | 44.7 | 34.3 | 21.0 | 25 | 980 | 1005 | |
| | Medina | Clinton | Sandstone, wanting | ---- | ---- | ---- | -- | 1005 | 1005 | Clinton sand of driller |
| | | Silhorn | Shale, reddish brown, fine grained | 59.2 | 22.4 | 18.4 | 55 | 1005 | 1060 | Red Medina of driller |
| Ordovician | Richmond | | Shale, dark grey, with thin limestone layers | 62.2 | 21.5 | 16.3 | 590 | 1060 | 1650 | Hudson River group of older writers |
| | Maysville | | Shale, dark grey, with thin limestone layers | | | | | | | |
| | Eden | | Shale, dark grey, with some nodular limestone | 72.4 | 16.2 | 11.4 | 280 | 1650 | 1930 | |
| | Utica | | Shale to shaly limestone, dark to brownish | 35.1 | 57.3 | 7.6 | 170 | 1930 | 2100 | Lower part impure limestone |
| | Trenton | | Limestone, light to dark, parts shaly | 14.8 | 78.9 | 6.3 | 150 | 2100 | 2250 | Trenton group of |
| | ? ? ? ? | | Limestone, light grey, pure | 3.9 | 88.8 | 7.3 | 406 | 2250 | 2656 | driller. Greenish shale at base so-called "St.Peter shale". Pronounced break in rocks |
| | Black River | | Shale, greenish with some limestone | 30.0 | 62.3 | 7.7 | 6 | 2656 | 2662 | |
| | | | Limestone, grey | 7.0 | 84.6 | 8.2 | 12 | 2662 | 2674 | |
| | | | Shale, greenish | ---- | ---- | ---- | 5 | 2674 | 2679 | |
| | St.Peter | | Sandstone, not detected by analysis | ---- | ---- | ---- | 0 | 2679 | 2679 | |
| Cambrian | Lower Magnesian | | Dolomite, light, granular, siliceous | 7.8 | 50.9 | 41.3 | 53 | 2679 | 2732 | Strong flow of brine; 2738-2760 |
| | ? ? ? | | Dolomite, pure, light, powdery | 2.3 | 54.2 | 43.5 | 118 | 2732 | 2850 | |
| | | | Dolomite, siliceous, light, granular | 8.4 | 51.0 | 40.6 | 50 | 2850 | 2900 | |
| | | | Dolomite, very pure, light, powdery | 1.4 | 55.0 | 43.6 | 170 | 2900 | 3070 | |
| | | | Dolomite, siliceous, light, granular | 5.0 | 52.7 | 42.3 | 60 | 3070 | 3130 | |
| | | | Dolomite, siliceous, light, granular | 18.2 | 45.1 | 36.7 | 40 | 3130 | 3170 | |
| | | | Sandstone, dolomitic, light, fine grained | 55.2 | 24.4 | 20.4 | 70 | 3170 | 3240 | |
| | | | Dolomite, dark, very sandy | 38.9 | 33.2 | 27.9 | 10 | 3240 | 3250 | |
| | | | Sandstone, dolomitic, dark, fine grained | 53.2 | 25.3 | 21.5 | 40 | 3250 | 3290 | |
| | | | Dolomite, dark, hard, very sandy | 41.0 | 31.9 | 27.1 | 65 | 3290 | 3355 | |
| | | | Sandstone, dolomitic, light, hard | 67.6 | 18.0 | 14.4 | 35 | 3355 | 3390 | |
| | | | Dolomite, grey, very sandy | 35.8 | 35.2 | 29.0 | 60 | 3390 | 3450 | |
| | | Jordan ? | Sandstone, light, hard, pure | 76.3 | 12.7 | 11.0 | 60 | 3450 | 3510 | Brine 3450-3455 |
| | | | Dolomite, grey, sandy | 47.3 | 46.3 | 36.1 | 65 | 3510 | 3575 | |
| | | | Sandstone, light, hard, pure | 74.5 | 13.8 | 11.7 | 10 | 3575 | 3585 | |
| | | | Dolomite, very sandy, grey | 29.1 | 39.9 | 31.0 | 45 | 3585 | 3630 | |
| | | | Sandstone, hard, pure | 67.3 | 17.6 | 15.1 | 30 | 3630 | 3660 | |
| | | | Dolomite, very sandy, dark, hard | 28.9 | 38.5 | 32.6 | 50 | 3660 | 3710 | |
| | | Dresbach | Sandstone, hard, very pure | 94.4 | 2.3 | 3.3 | 135 | 3710 | 3845 | Brines at 3775-3786, and 3820-3825 |
| Pre-Cambrian | | | Crystalline rocks, mainly gneiss | ---- | ---- | ---- | 446 | 3845 | 4291 | |

### ROCK SECTION

The general stratigraphic section in Ohio includes rocks from the pre-Cambrian crystalline formations to about the top of the eastern Permian group. Those appearing at the surface and thus permitting examination include those from the Cynthiana formation at the top of the Trenton to the Gilmore sandstone in the Dunkard. Below the Trenton the information gained is from oil and gas wells or from studying distant outcrops. In the Vance well about 2,000 feet of drillings may be compared with rocks at the surface. The strata in the well are found to be quite consistent with those at the surface in thickness, composition, and physical properties. From a depth of 2,000 feet to the crystalline rocks little attempt is made at correlation for only a few holes have penetrated the lower strata and their outcrops are far distant.

### ROCKS OF DEVONIAN SYSTEM

Drilling in the Vance well began in the Ohio shale, the "Big Cinnamon" of the driller, not far above the zone of large concretions which caused some trouble in drilling. The rocks next penetrated were the soft Olentangy shale and the flinty Delaware limestone, both exposed along the Olentangy River near by. The formation next found was the Columbus limestone, normal in thickness and properties and well exposed along the Scioto River, about 5 miles west.

The Oriskany sandstone of the eastern fields and all the members of the Detroit River group of northern Ohio and Michigan were wanting, thus creating an unconformity representing considerable time. This break, however, is not marked by much irregularity of bedding where it is exposed at several places 10–20 miles northwest, but is definitely fixed by a thin layer of black tarry bitumen between the Monroe dolomite and the overlying Columbus limestone. In some places a few inches of green shale appears above the bitumen layer. Along this unconformity is the horizon of the "First water" in the "Big lime" of the Ohio driller.

### ROCKS OF SILURIAN SYSTEM

The rocks of the Silurian system are well exposed in western Ohio and have been much explored by drilling throughout eastern Ohio. This system with many dolomite and some limestone members reaches its maximum thickness in eastern Ohio along an axis from Painesville on Lake Erie to East Liverpool on the Ohio River. Its thickness is not far from 1,500 feet at the former place and 2,000 feet at the latter.

Some of the prominent formations of the Silurian system are discussed.

MONROE GROUP

In the Vance well the Monroe group of dolomites, 400 feet in thickness, consisted of thin to medium beds of dolomite, much alike in the entire thickness. These rocks are slightly siliceous in character, vary from bluish gray to dark brown in color, change from hard, dense, to open, sugary in texture and appear from distinctly laminated to brecciated, to massive in structure. Mud cracks and ripple marks are common impressions. In the Monroe dolomites the fossils are not abundant and are small in size. The anhydrite deposits of central and northern Ohio and the salt beds of eastern Ohio are ordinarily about midway in the Monroe section. This group of rocks in Ohio is approximately correlative with the Salina of New York.

GREEN SHALE

One of the most definite unconformities appearing at the surface in Ohio is that between the Monroe and Niagara groups of rocks. This break is commonly marked by green shale, by tarry bitumen, or by both. Where both shale and bitumen appear the former is above the latter. Such green shale is evident at many breaks throughout the Ohio column from the Cambrian to the Pennsylvanian rocks. The shale represents the residue from the dolomite or limestone and was liberated through solution and was deposited as a residual.

The section taken by J. E. Carman and W. Stout follows.

| | *Feet* |
|---|---|
| Monroe formation | |
| Dolomite, rather regularly bedded; beds massive except near top where thin to medium; some strata finely crystalline and dense, others coarsely crystalline and cavernous; stone light to dark gray in color; few fossils | 27 |
| Unconformity: shale, soft, argillaceous, from less than one inch to several feet in thickness, bluish gray to greenish to dark in color | 1 |
| Niagara formation | |
| Dolomite, very massive, open, cavernous texture, light color, large fossils common | 30 |

The following analysis of the greenish shale at the Monroe-Niagara unconformity was made by Downs Schaaf.

| | *Percentage* |
|---|---|
| Silica, $SiO_2$ | 46.93 |
| Alumina, $Al_2O_3$ | 17.48 |
| Ferric oxide, $Fe_2O_3$ | 1.88 |
| Ferrous oxide, $FeO$ | 0.95 |
| Pyrite, $FeS_2$ | 4.91 |
| Magnesium oxide, $MgO$ | 3.65 |
| Calcium oxide, $CaO$ | 3.35 |
| Strontium oxide, $SrO$ | none |
| Barium oxide, $BaO$ | <0.01 |

| | Percentage |
|---|---|
| Sodium oxide, $Na_2O$ | 1.90 |
| Potassium oxide, $K_2O$ | 2.25 |
| Water, hydroscopic, $H_2O-$ | 3.60 |
| Water, combined, $H_2O+$ | 6.05 |
| Carbon dioxide, $CO_2$ | 5.90 |
| Titanic oxide, $TiO_2$ | 0.92 |
| Phosphorous pentoxide, $P_2O_5$ | <0.01 |
| Sulphur trioxide, $SO_3$ | 0.24 |
| Manganese oxide, $MnO$ | 0.03 |
| Vanadium oxide, $V_2O_5$ | <0.01 |
| Carbon, organic, $C$ | 0.10 |
| Hydrogen, organic, $H$ | 0.02 |
| Total | 100.16 |

As determined by calculation from the analysis (Stout) the mineral components in this green shale are as follows.

| | | | Percentage |
|---|---|---|---|
| Sericite, $(K, Na)_2O \cdot 3Al_2O_3 \cdot 6SiO_2 \cdot 2H_2O$ | | | 18.13 |
| Kaolinite, $Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$ | | | 26.46 |
| Celadonite, $(Fe, Mg, K_2, Na_2)O \cdot 2SiO_2 \cdot H_2O : Fe_2O_3 \cdot 6SiO_2 \cdot 3H_2O$ | | | 15.09 |
| Quartz or free silica, $SiO_2$ | | | 17.02 |
| Limonite, $2Fe_2O_3 \cdot 3H_2O$ | | | 1.03 |
| Pyrite, $FeS_2$ | | | 4.91 |
| Rutile, $TiO_2$ | | | 0.92 |
| Apatite, $3CaO \cdot P_2O_5$ | | | 0.00 |
| Anhydrite, $CaO \cdot SO_3$ | | | 0.41 |
| Dolomite — Main components | $MgO \cdot CO_2$ | 5.75 | |
| | $CaO \cdot CO_2$ | 5.68 | |
| Dolomite — Parts in solid solution | $FeO \cdot CO_2$ | 1.00 | 11.43 |
| | $MnO \cdot CO_2$ | 0.05 | 1.05 |
| Water, hydroscopic, $H_2O$ | | | 3.60 |
| Unbalanced parts (excess $CO_2$, $H_2O$) | | | −0.01 |
| Total | | | 100.16 |

These green shales are not bentonite or bentonitic in any respect. The green pigment is celadonite, one of the glauconite minerals, and was derived through the gradual change of muscovite to sericite to celadonite. In this transformation the original mineral lost alumina but increased in iron oxides, magnesia and potash. An analysis, by Downs Schaaf, of the green grains separated by heavy minerals (Priddy) and then careful selection is given here.

| | Percentage |
|---|---|
| Silica, $SiO_2$ | 59.0 |
| Alumina, $Al_2O_3$ | 11.1 |
| Ferric oxide, $Fe_2O_3$ | 7.8 |
| Ferrous oxide, $FeO$ | 6.6 |
| Calcium oxide, $CaO$ | 0.1 |
| Magnesium oxide, $MgO$ | 6.5 |
| Potassium oxide, $K_2O$ | 6.6 |
| Sodium oxide, $Na_2O$ | 1.4 |
| Others | 0.9 |
| Total | 100.0 |

The formula for the celadonite mineral appears to be $(Fe, Mg, K_2, Na_2)O \cdot 2SiO_2 \cdot H_2O : Fe_2O_3 \cdot 6SiO_2 \cdot 3H_2O$. The composition is some-

what variable as *Fe*, *Mg*, $K_2$, and $Na_2$ may substitute one for another. Also the amounts of $Fe_2O_3$ and *FeO* change with different samples. Celadonite is one of the glauconite minerals and in no way related to bentonite.

NIAGARA GROUP

In Ohio the Niagara group of rocks is made up of four formations which in ascending order are Euphemia, Springfield, Cedarville, and Guelph. The Euphemia and Springfield are generally thin, 6 and 10 feet, respectively, but the Cedarville and Guelph are massive, persistent formations. This group varies from 120 to 200 feet in thickness but averages about 170 feet. All are dolomites. The Guelph has remarkable purity, in many places exceeding 99.50 per cent dolomite whereas the Cedarville is also of high grade, generally exceeding 98 per cent dolomite. The Newburg sand of the driller is only the top of the Niagara dolomite. This horizon has been productive in several pools near Cleveland and in stray wells southward to the Ohio River. The upper part of the Niagara dolomite is also the horizon of the "Second water" in the "Big lime." Generally the flow is large and the concentration high. In the Vance well the thickness of the Niagara group was 140 feet and the rock dolomite of fair purity.

CLINTON GROUP

The Clinton group of Ohio consists of calcareous shale, calcareous dolomite and limestone. The general thickness ranges from 120 to 200 feet with an average of about 150 feet. The recognized units in ascending order are Brassfield limestone, Dayton dolomite, and Alger shale with a thin dolomite, Laurel, in the upper part. The Alger shale underlying the Niagara dolomite is the Niagara shale of the older drillers and is correlative with the Rochester shale of the New York section. The Dayton and Brassfield formations constitute the "Little lime" or "shell" of the driller. Both formations are variable in thickness and in composition for considerable shale may be interbedded in these carbonate rocks.

In the Vance well the Alger shale is about 50 feet in thickness and contains some thin dolomite layers. The Dayton formation is dolomitic in character and interbedded in shale. The Brassfield, everywhere a limestone at the surface in Ohio, is a calcareous dolomite with about its ordinary thickness, 45 feet.

MEDINA GROUP

The Medina group of rocks in Ohio and stratigraphically correlative with those in western New York is well represented in the eastern

part of the state. The two units are the Clinton sand, yielding great gas and oil fields and the "Red Medina," physically one of the most definite units in the entire column. The Elkhorn shale of Ohio is the "Red Medina" of the driller and the Queenstown shale of the Niagara Falls, New York, section.

No evidence of the Clinton sand was found in the Vance well, the edge of the producing fields being about 25 miles east. The "Red Medina," however, was a very conspicuous unit and was about 55 feet in thickness. An analysis (Downs Schaaf) of the Red Medina shale is given.

| | *Percentage* |
|---|---|
| Silica, $SiO_2$ | 42.80 |
| Alumina, $Al_2O_3$ | 13.99 |
| Ferric oxide, $Fe_2O_3$ | 2.44 |
| Ferrous oxide, $FeO$ | 1.46 |
| Pyrite, $FeS_2$ | 0.15 |
| Magnesium oxide, $MgO$ | 7.88 |
| Calcium oxide, $CaO$ | 8.93 |
| Sodium oxide, $Na_2O$ | 0.47 |
| Potassium oxide, $K_2O$ | 3.95 |
| Water, hydroscopic, $H_2O-$ | 1.22 |
| Water, combined, $H_2O+$ | 2.95 |
| Carbon dioxide, $CO_2$ | 12.87 |
| Titanic oxide, $TiO_2$ | 0.59 |
| Zirconium oxide, $ZrO_2$ | <0.01 |
| Phosphorus pentoxide, $P_2O_5$ | 0.28 |
| Sulphur trioxide, $SO_3$ | <0.01 |
| Manganese oxide, $MnO$ | 0.12 |
| Carbon, organic, $C$ | 0.05 |
| Total | 100.15 |

As calculated from the analysis the mineral composition of the Red Medina shale is as follows.

| | | | | *Percentage* |
|---|---|---|---|---|
| Sericite, $(K,Na)_2 \cdot 3Al_2O_3 \cdot 6SiO_2 \cdot 2H_2O$ | | | | 32.28 |
| Biotite, $(4MgO, K_2O) \cdot 2Al_2O_3 \cdot 6SiO_2 \cdot H_2O$ | | | | 6.24 |
| Kaolinite, $Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$ | | | | 0.00 |
| Celadonite, $(Fe, Mg, K_2, Na_2)O \cdot 2SiO_2 : Fe_2O_3 \cdot 6SiO_2 \cdot 3H_2O$ | | | | 14.14 |
| Quartz or free Silica, $SiO_2$ | | | | 16.53 |
| Limonite, $2Fe_2O_3 \cdot 3H_2O$ | | | | 0.12 |
| Hematite, $Fe_2O_3$ | | | | 1.09 |
| Pyrite, $FeS_2$ | | | | 0.15 |
| Rutile, $TiO_2$ | | | | 0.59 |
| Apatite, $3CaO \cdot P_2O_5$ | | | | 0.60 |
| Anhydrite, $CaO \cdot SO_3$ | | | | 0.00 |
| Dolomite | Main components | $MgO \cdot CO_2$ | 11.48 | 26.85 |
| | | $CaO \cdot CO_2$ | 15.37 | |
| | Parts in solid solution | $FeO \cdot CO_2$ | 0.10 | |
| | | $MnO \cdot CO_2$ | 0.19 | 0.29 |
| Water, hydroscopic, $H_2O-$ | | | | 1.22 |
| Hydrocarbons, $C_nH_{2n+2}$ | | | | 0.05 |
| Unbalanced parts ($CO_2$, $H_2O$) | | | | 0.00 |
| Total | | | | 100.15 |

On washing and close inspection the Red Medina shows much of the green coloring pigment blended with the hematite. The high potassium oxide shows the presence of sericite, biotite, and celadonite. Aside from hematite as a coloring pigment this shale is similar to others in Devonian, Silurian, and Ordovician systems.

RICHMOND, MAYSVILLE, AND EDEN GROUPS

Physically the Richmond and Maysville groups are very similar. Both consist mainly of dark bluish to greenish gray calcareous shales in which thin-bedded limestones are rather regularly but widely spaced. The limestone layers constitute 25–50 per cent of the whole but average about 35 per cent. They vary in thickness from less than $\frac{1}{4}$ inch to 10 inches. Both shale and limestone are highly fossiliferous.

The Eden group is much like the foregoing except for an impoverishment in limestone. It consists largely of the bluish to greenish gray calcareous shale in which limestone is widely spaced and consists of nodular layers or thin beds few of which are more than a few inches in thickness. Like the foregoing formations both shale and limestone are highly fossiliferous with well preserved specimens. The analyses of the shale and limestone of the Eden group are of interest.

The composition of the limestone and of the shale in the Eden formation is as follows, according to analyst Downs Schaaf.

| | *Percentage* | |
|---|---|---|
| | *Limestone* | *Shale* |
| Silica, $SiO_2$ | 8.77 | 45.50 |
| Alumina, $Al_2O_3$ | 2.80 | 14.02 |
| Ferric oxide, $Fe_2O_3$ | 0.33 | 1.90 |
| Ferrous oxide, $FeO$ | 1.17 | 3.38 |
| Pyrite, $FeS_2$ | 0.18 | 1.61 |
| Magnesium oxide, $MgO$ | 1.20 | 2.95 |
| Calcium oxide, $CaO$ | 46.31 | 9.80 |
| Strontium oxide, $SrO$ | none | none |
| Barium oxide, $BaO$ | <0.01 | <0.01 |
| Sodium oxide, $Na_2O$ | 0.12 | 0.65 |
| Potassium oxide, $K_2O$ | 0.14 | 3.75 |
| Water, hydroscopic, $H_2O-$ | 0.27 | 1.27 |
| Water, combined, $H_2O+$ | 0.74 | 3.74 |
| Carbon dioxide, $CO_2$ | 37.49 | 9.90 |
| Titanium oxide, $TiO_2$ | 0.17 | 0.88 |
| Phosphorus pentoxide, $P_2O_5$ | 0.20 | 0.44 |
| Sulphur trioxide, $SO_3$ | <0.01 | 0.14 |
| Manganese oxide, $MnO$ | 0.09 | 0.11 |
| Vanadium oxide, $V_2O_5$ | <0.01 | <0.01 |
| Carbon, organic, $C$ | 0.07 | 0.28 |
| Hydrogen, organic, $H$ | 0.01 | 0.04 |
| Total | 100.06 | 100.36 |

The points of interest are the high content of ferrous oxide, $FeO$, and of potassium oxide, $K_2O$. Both shale and limestone are also high in pyrite, $FeS_2$, and in hydrocarbons, $C_nH_{2n+2}$.

The mineral composition of the limestone as determined by calculation from the analysis is as follows.

| | | | *Percentage* |
|---|---|---|---|
| Sericite, $(K, Na)_2O \cdot 3Al_2O_3 \cdot 6SiO_2 \cdot 2H_2O$ | | | 2.21 |
| Biotite, $(4MgO \cdot K_2O) \cdot 2Al_2O_3 \cdot 6SiO_2 \cdot H_2O$ | | | 0.46 |
| Kaolinite, $Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$ | | | 4.58 |
| Celadonite, $(Fe, Mg, K_2, Na_2)O \cdot 2SiO_2 \cdot H_2O : Fe_2O_3 \cdot 6SiO_2, 3H_2O$ | | | 4.08 |
| Quartz or free silica, $SiO_2$ | | | 3.03 |
| Limonite, $2Fe_2O_3 \cdot 3H_2O$ | | | 0.09 |
| Pyrite, $FeS_2$ | | | 0.18 |
| Rutile, $TiO_2$ | | | 0.17 |
| Apatite, $3CaO \cdot P_2O_5$ | | | 0.42 |
| Anhydrite, $CaO \cdot SO_3$ | | | 0.00 |
| Limestone — Main components | $MgO \cdot CO_2$ | 2.32 | |
| | $CaO \cdot CO_2$ | 82.26 | 84.58 |
| Limestone — Parts in solid solution | $FeO \cdot CO_2$ | 0.13 | |
| | $MnO \cdot CO_2$ | 0.15 | 0.28 |
| Water, hydroscopic, $H_2O-$ | | | 0.27 |
| Hydrocarbons, $C_nH_{2n+2}$ | | | 0.08 |
| Unbalanced parts (excess $CO_2$, $H_2O$) | | | −0.37 |
| Total | | | 100.06 |

The mineral composition of the shale as determined by calculation from the analysis follows.

| | | | *Percentage* |
|---|---|---|---|
| Sericite, $(K, Na)_2O \cdot 3Al_2O_3 \cdot 6SiO_2 \cdot 2H_2O$ | | | 31.43 |
| Biotite, $(4MgO \cdot K_2O) \cdot 2Al_2O_3 \cdot 6SIO_2 \cdot H_2O$ | | | 1.60 |
| Kaolinite, $Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$ | | | 3.70 |
| Celadonite, $(Fe, Mg, K_2, Na_2)O \cdot 2SiO_2 \cdot H_2O : Fe_2O_3 \cdot 6SiO_2 \cdot 3H_2O$ | | | 19.29 |
| Quartz or free silica, $SiO_2$ | | | 17.28 |
| Limonite, $2Fe_2O_3 \cdot 3H_2O$ | | | 0.11 |
| Pyrite, $FeS_2$ | | | 1.61 |
| Rutile, $TiO_2$ | | | 0.88 |
| Apatite, $3CaO \cdot P_2O_5$ | | | 0.96 |
| Anhydrite $CaO \cdot SO_3$ | | | 0.24 |
| Limestone — Main components | $MgO \cdot CO_2$ | 4.89 | |
| | $CaO \cdot CO_2$ | 16.39 | 21.28 |
| Limestone — Parts in solid solution | $FeO \cdot CO_2$ | 0.19 | |
| | $MnO \cdot CO_2$ | 0.18 | 0.37 |
| Water, hydroscopic, $H_2O-$ | | | 1.27 |
| Hydrocarbons, $C_nH_{2n+2}$ | | | 0.32 |
| Unbalanced parts (lacking $CO_2$, $H_2O$) | | | +0.02 |
| Total | | | 100.36 |

As thus determined the shale shows an exceptionally high content of both sericite and celadonite, the latter being only an advanced stage of change from the former. The limestone also contains the same mineral components but in smaller quantities. In both the shale and limestone the green mineral celadonite is apparent to the eye and definitely so to the microscope. Both sericite and celadonite appear to be common ingredients of most of the bluish and greenish colored shales and limestones, regardless of the part of the geological column in which they may be found.

Green or bluish green shales of this type are produced through the normal deposition of fine silts in marine waters. One of the few reactions of the ocean is to reduce oxides from a higher to a lower state. Thus, silty materials, high in micas, enter the ocean from the uplands and are immediately attacked by organic life for any available oxygen. Ferric oxide, $Fe_2O_3$, is reduced to ferrous oxide, $FeO$, and ferrous sulphate, $FeSO_4$, is broken down to pyrite, $FeS_2$. Such mineral components as glauconite, celadonite, and pyrite are normal for marine conditions and on account of their reduced oxides act as coloring pigments. Green shales are simply normal deposits, a product of oceanic deposition.

### UTICA GROUP

The Utica group of the New York section is definitely present throughout Ohio and apparently has all the characteristics. These rocks are well developed in the northern and eastern parts of the state but become thin in the southwestern part where they make their appearance along the Ohio valley and have been designated Fulton. The Utica consists of shale and shaly limestone, brown to greenish to dark in color, and fine, compact in texture. In Ohio, according to drillers logs, the Utica varies from 50 to 400 feet in thickness but averages close to 170 feet.

In the Vance well the Utica was a definite unit about 150 feet in thickness and consisted of brown shale and dark carbonaceous limestone. As determined by the rough analysis the composition of the formation consists of 35 per cent of shaly and siliceous matter and about 65 per cent of limestone. No well defined break is apparent between the Utica and the underlying Trenton. The composition of the Utica more nearly approaches that of the underlying Trenton than it does the overlying Eden.

### TRÉNTON AND BLACK RIVER GROUPS

The Trenton and Black River groups in Ohio are, in general, under deep cover and have always been lumped by the driller into one unit, designated Trenton. The rocks in both formations are similar in chemical and physical properties and on this account require technical determination by the microscope for separation. They vary in composition from limestone to dolomite but in the main are largely the former. They change from light to dark gray in color and from dense to open texture, depending on whether a limestone or a dolomite. In the great Trenton field of northwestern Ohio production was confined to dolomite or calcareous dolomite and was influenced more by porosity than by structure. Where the rock changed to limestone the den-

sity was too great to permit accumulation. In Ohio the combined thickness of the Trenton and Black River varies from 470 to 1,200 feet but the usual measurement is between 580 and 700 feet. About one-fourth of this section appears to be Trenton and the remainder Black River.

Throughout much of Ohio a well pronounced break or unconformity occurs between the Black River group and the older formations of the St. Peter and Lower Magnesian groups. This break is commonly marked by bluish green shale; hence, often designated "green shale" by the driller. Such shale occurs commonly just above the unconformity and is evidently formed from the residue of carbonate rock that has been lost by solution. The green pigment appears to be the glauconitic mineral, celadonite, that gives color to shales, limestones, and dolomites throughout most of the column.

An analysis of "green shale" at this horizon follows.

| | *Percentage* |
|---|---|
| Silica, $SiO_2$ | 40.48 |
| Alumina, $Al_2O_3$ | 13.80 |
| Ferric oxide, $Fe_2O_3$ | 1.61 |
| Ferrous oxide, $FeO$ | 1.69 |
| Pyrite, $FeS_2$ | 0.75 |
| Magnesium oxide, $MgO$ | 7.99 |
| Calcium oxide, $CaO$ | 9.50 |
| Sodium oxide, $Na_2O$ | 0.70 |
| Potassium oxide, $K_2O$ | 4.25 |
| Water, hydroscopic, $H_2O-$ | 2.57 |
| Water, combined, $H_2O+$ | 3.25 |
| Carbon dioxide, $CO_2$ | 12.80 |
| Titanium oxide, $TiO_2$ | 0.52 |
| Zirconium oxide, $ZrO_2$ | <0.01 |
| Phosphorous pentoxide, $P_2O_5$ | 0.20 |
| Sulphur trioxide, $SO_3$ | 0.02 |
| Manganous oxide, $MnO$ | 0.04 |
| Carbon, organic, $C$ | 0.03 |
| Total | 100.15 |

In this analysis the high content of potassium oxide, $K_2O$, indicates an excess of micas and their derivatives. This shale in composition is comparable with many others throughout the Ohio column. It is high in sericite, biotite, and celadonite. As calculated from the analysis the mineral composition is as follows.

| | *Percentage* |
|---|---|
| Sericite, $(K, Na)_2O \cdot 3Al_2O_3 \cdot 6SiO_2 \cdot 2H_2O$ | 30.90 |
| Biotite, $(4MgO, K_2O) \cdot 2Al_2O_3 \cdot 6SiO_2 \cdot H_2O$ | 7.65 |
| Kaolinite, $Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$ | 0.00 |
| Celadonite, $(Fe, Mg, K_2, Na_2)O \cdot 2SiO_2 \cdot H_2O : Fe_2O_3 \cdot 6SiO_2 \cdot 3H_2O$ | 18.40 |
| Quartz or free silica, $SiO_2$ | 11.59 |
| Limonite, $2Fe_2O_3 \cdot 3H_2O$ | 0.14 |
| Pyrite, $FeS_2$ | 0.75 |
| Rutile, $TiO_2$ | 0.52 |
| Apatite, $3CaO \cdot P_2O_5$ | 0.46 |

| | | | | Percentage |
|---|---|---|---|---|
| Anhydrite, $CaO \cdot SO_3$ | | | | 0.03 |
| Dolomite | Main components | $MgO \cdot CO_2$ | 10.56 | |
| | | $CaO \cdot CO_2$ | 16.47 | 27.03 |
| | Parts in solid solution | $FeO \cdot CO_2$ | 0.08 | |
| | | $MnO \cdot CO_2$ | 0.06 | 0.14 |
| Water, hydroscopic, $H_2O-$ | | | | 2.57 |
| Hydrocarbons, $C_nH_{2n+2}$ | | | | 0.03 |
| Unbalanced parts (excess $CO_2$, $H_2O$) | | | | −0.06 |
| Total | | | | 100.15 |

The green and bluish green pigments in the shale at the St. Peter horizon are thus the micas, sericite and biotite, and their altered component, celadonite. Such coloring matter occurs in shale, dolomite and limestone throughout the Ohio column. There is no basis for interpreting such shale as bentonite.

The composition of a few typical bentonites is as follows.[4]

| | *No. 1* | *No. 2* | *No. 7* | *No. 11* |
|---|---|---|---|---|
| Silica, $SiO_2$ | 61.5 | 55.22 | 45.52 | 67.2 |
| Alumina, $Al_2O_3$ | 21.2 | 21.00 | 27.52 | 18.6 |
| Ferric oxide, $Fe_2O_3$ | .1 | 3.61 | 2.80 | .7 |
| Titanic oxide, $TiO_2$ | — | — | — | — |
| Calcium oxide, $CaO$ | .4 | 4.94 | .52 | .9 |
| Magnesium oxide, $MgO$ | 1.1 | 3.04 | 3.00 | 1.9 |
| Potassium oxide, $K_2O$ | .2 | — | — | trace |
| Sodium oxide, $Na_2O$ | 1.8 | 1.56 | — | 2.1 |
| Water at 105°C. | — | — | — | 7.55 |
| Water, total | 8.61 | 10.28 | 19.60 | 8.55 |

No. 1, Bentonite, near Fallon, Nev.
No. 2, Bentonite, near Ardmore, S. D.
No. 7, Bentonite, Mine Creek, Ark.
No. 11, Bentonite, from Trojan Mining Co., Deadwood, S. D.

In the true bentonites the potassium oxide, $K_2O$, is low and other bases, as sodium oxide, $Na_2O$, and ferric oxide, $Fe_2O_3$, are variable, apparently entering little into the fixed components. The combined water is high, indicating its colloidal nature. Such materials vary through a wide range of color from light, through olive, green, gray, brown, and pink to black. The chief characteristic is swelling when moistened. Both physically and chemically the bentonites are very different from the bluish and bluish green calcareous shales of Ohio.

For comparison the shales in the Ohio formations are grouped. Two of these shales are at unconformities and two in the regular formations. They agree closely in all the main components and represent a wide range in the geological column. The outstanding feature of all is the alkalies, well above 4 per cent.

SHALES OF OHIO

| | *No. 1* | *No. 2* | *No. 3* | *No. 4* |
|---|---|---|---|---|
| Silica, $SiO_2$ | 46.93 | 42.80 | 45.50 | 40.48 |
| Alumina, $Al_2O_3$ | 17.48 | 13.99 | 14.02 | 13.80 |

[4] C. W. Davis and H. C. Vacher, "Bentonite: Its Properties, Mining, Preparation and Utilization." *U. S. Bur. Mines Tech. Paper 438.*

| | No. 1 | No. 2 | No. 3 | No. 4 |
|---|---|---|---|---|
| Ferric oxide, $Fe_2O_3$ | 1.88 | 2.44 | 1.90 | 1.61 |
| Ferrous oxide, $FeO$ | 0.95 | 1.46 | 3.38 | 1.69 |
| Pyrite, $FeS_2$ | 4.91 | 0.15 | 1.61 | 0.75 |
| Magnesium oxide, $MgO$ | 3.65 | 7.88 | 2.95 | 7.99 |
| Calcium oxide, $CaO$ | 3.35 | 8.93 | 9.80 | 9.50 |
| Strontium oxide, $SrO$ | none | — | none | — |
| Barium oxide, $BaO$ | <0.01 | — | <0.01 | — |
| Sodium oxide, $Na_2O$ | 1.90 | 0.47 | 0.65 | 0.70 |
| Potassium oxide, $K_2O$ | 2.25 | 3.95 | 3.75 | 4.25 |
| Water, hydroscopic, $H_2O-$ | 3.60 | 1.22 | 1.27 | 2.57 |
| Water, combined, $H_2O+$ | 6.05 | 2.95 | 3.74 | 3.25 |
| Carbon dioxide, $CO_2$ | 5.90 | 12.87 | 9.90 | 12.80 |
| Titanic oxide, $TiO_2$ | 0.92 | 0.59 | 0.88 | 0.52 |
| Phosphorous pentoxide, $P_2O_5$ | <0.01 | 0.28 | 0.44 | 0.20 |
| Sulphur trioxide, $SO_3$ | 0.24 | <0.01 | 0.14 | 0.02 |
| Manganese oxide, $MnO$ | 0.03 | 0.12 | 0.11 | 0.04 |
| Vanadium oxide, $V_2O_5$ | <0.01 | — | <0.01 | — |
| Carbon, organic, $C$ | 0.10 | 0.05 | 0.28 | 0.03 |
| Hydrogen, organic, $H$ | 0.02 | — | 0.04 | — |
| Total | 100.16 | 100.15 | 100.36 | 100.15 |

No. 1, Shale at Niagara-Monroe unconformity.
No. 2, Shale of Red Medina formation.
No. 3, Shale of Eden formation.
No. 4, Shale at St. Peter horizon.

The record of the Vance well in the Trenton and Black River groups with the "green shale" at the base of the latter is interesting. The entire thickness of the two groups is 579 feet and the composition throughout the section is that of limestone. The quality of the rock, however, varies from siliceous to pure. The underlying Lower Magnesian formations are notably different. The rock throughout this part of the column is dolomite, free from impurities except here and there sandy enrichments. Some of these may be thin lenses of sandstone in the dolomite. The unconformity here marks the approximate horizon of the true St. Peter sand and also that of the so-called "Blue lick" water which is abnormally weak for the depth.

### LOWER MAGNESIAN ROCKS

The Lower Magnesian rocks in Ohio have not been well defined as to their relation to the overlying and underlying formations and as to the particular units represented. The rocks are true dolomites with high purity and with textures varying from powdery to coarsely granular. Locally some thin sandstones and sandy lenses appear, most commonly in the upper part of the group.

In the Vance well this group of rocks seems to be about normal for western Ohio; that is, it is made up of dolomites with some sandy lenses appearing throughout the section. Its differentiation from the Cambrian below is not certain.

### CAMBRIAN SYSTEM

In the Vance well the Cambrian rocks are decidedly outstanding in that they contain such a high content of sandy material. In fact the sandstones, either pure or dolomite bonded, make up more than half of the total section. Likewise the dolomite strata are slightly to very sandy in composition. The formations with the cleanest quartz sand are those in the lower part of the system. The one most conspicuous lies directly on the crystalline rocks from 3,710 to 3,845 feet. Other sand strata of high purity occur from 3,450 to 3,510 feet, from 3,575 to 3,585 feet, and from 3,625 to 3,660 feet. In this well little or no granite wash is present; the bit passed almost directly from clean quartz sand to crystalline rocks. Under such conditions the Cambrian appears to have been deposited on the much eroded but not highly weathered surface of the crystalline rocks.

## PRE-CAMBRIAN SECTION

### PROCEDURE

In order to obtain a fairly accurate quantitative description of the pre-Cambrian section of the Vance well, a somewhat detailed examination of each sample was necessary. After screening to remove material more than 0.495 millimeter in size, the finer material, which constituted the bulk of the sample, was washed with dilute sodium hydroxide solution and dried. The magnetic material was then removed with a large horseshoe magnet and treated with nitric acid to dissolve fragments of drill bit, after which the residue of magnetite was weighed. A representative fraction of the non-magnetic part, weighing 10–15 grams, was selected by coning and quartering or by using a sample splitter. This representative sample was then separated into a light and a heavy fraction by means of Thoulet solution, specific gravity 3.1, and, after drying, each fraction was weighed. Thus by magnetic treatment and the use of heavy liquid there was effected a quantitative separation of the lighter and the heavier constituents.

Both the light and heavy fractions of each sample were then examined microscopically, grains being mounted in oil. A somewhat modified Rosiwal analysis of each sample of the light fraction was made in order to obtain a quantitative estimate of the amount of quartz and feldspar present. A mechanical stage was used, but after some practice it was found that many estimates of grain size could be made. Although this procedure reduced the accuracy of the analyses

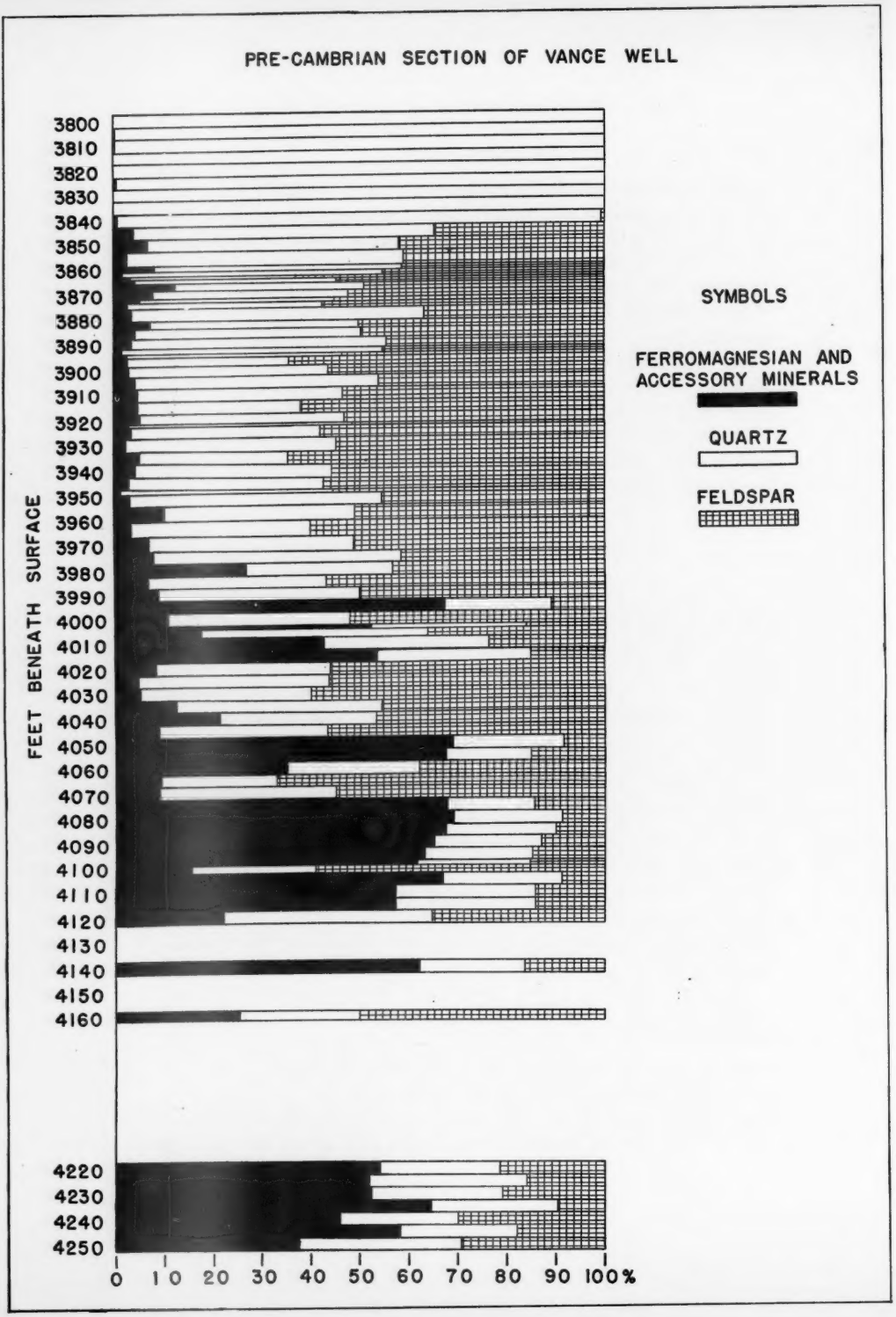
PRE-CAMBRIAN SECTION OF VANCE WELL
FEET BENEATH SURFACE
3800
3810
3820
3830
3840
3850
3860
3870
3880
3890
3900
3910
3920
3930
3940
3950
3960
3970
3980
3990
4000
4010
4020
4030
4040
4050
4060
4070
4080
4090
4100
4110
4120
4130
4140
4150
4160
4220
4230
4240
4250
0 10 20 30 40 50 60 70 80 90 100%
SYMBOLS
FERROMAGNESIAN AND ACCESSORY MINERALS
QUARTZ
FELDSPAR

FIG. 1

to some extent, it very materially increased the rapidity with which determinations were made, and it is believed that the results obtained approximate fairly closely the actual percentages of quartz and feldspar present. A similar method was used for estimating the percentages of biotite and hornblende in the heavy fractions, but determinations were made only at such intervals as were deemed necessary to obtain the general trend of increase or decrease of these minerals.

Eighty-four samples were treated in the manner outlined. Most of these samples were taken at intervals of 5 feet, but a few of them were taken at smaller intervals. They represent all material available with the exception of a few samples between 4,120 and 4,155 feet. No samples were obtained between 4,160 and 4,215 feet.

## MINERAL COMPOSITION

The accompanying graph (Fig. 1) shows the percentages of heavy minerals, of quartz, and of feldspar in each of the samples studied. Although the graph shows mineral groups merely as ferromagnesian and accessory minerals, quartz, and feldspar, there is a considerable amount of variation in each one of these subdivisions.

The ferromagnesian minerals present are chiefly biotite and hornblende, with smaller amounts of magnetite. Hornblende is not present above a depth of 3,915 feet. Below that depth the percentages of hornblende and biotite are somewhat variable, but down to about 3,980 feet the presence of more biotite than hornblende is characteristic, some samples containing twice as much biotite as hornblende. Thereafter the percentage of hornblende increases, and many samples below 4,000 feet contain from seven to nine times as much hornblende as biotite. Magnetite is present in variable amounts, but down to a depth of 4,050 feet it constitutes 10–25 per cent of the total quantity of ferromagnesian and accessory minerals, although exceptionally it makes up 50 per cent of the total quantity of heavy minerals. In such exceptional cases the total amount of heavy minerals is small. Between 4,050 and 4,235 feet the percentage of magnetite decreases, and it rarely constitutes more than 1 per cent of the total amount of heavy minerals. However, in the lowermost samples, between 4,235 and 4,250 feet, the amount of magnetite again increases, and it makes up 3–8 per cent of the total heavy minerals.

The principal accessory minerals present are zircon, garnet, and apatite, but some samples contain, also, traces of rutile, tourmaline, and epidote. Apatite is not present above a depth of 3,845 feet, and all accessory minerals above that depth are well rounded and do not show much crystal form. Zircons are characteristically elongate, but

show no crystal faces. At 3,845 feet and below, accessory minerals are not eroded and show crystal form well. Zircon, especially, is in well developed crystals with very sharp pyramidal terminations and zonal striations perfectly shown on prism faces. In general, accessory minerals are more abundant in those zones that do not contain large amounts of ferromagnesian minerals.

Quartz does not show much variation throughout the well. The chief points of interest are the fact that it is in well rounded, eroded grains above 3,845 feet and in angular, uneroded fragments below that depth, and that toward the lower part of the well some of it is crowded with inclusions, apparently apatite, zircon, and perhaps monazite.

Feldspar, which is an important constituent of all samples below a depth of 3,840 feet, consists of microcline, microcline-perthite, and plagioclase. Microcline is the most abundant variety present, and occurs characteristically in those samples that do not contain great quantities of ferromagnesian minerals, but is present in some abundance in all samples. Sodic varieties of plagioclase near oligoclase in composition are the characteristic representatives of the plagioclase division, but some feldspar almost as calcic as labradorite is present in some samples, especially in those containing large amounts of hornblende. Exceptionally, some of the potassic feldspar present shows myrmekitic texture.

Variations in mineral composition indicate the presence of three significant horizons, at 3,840, 3,975, and 4,075 feet, respectively, characterized by marked changes in the percentages of heavy minerals, quartz, and feldspar. These changes indicate the presence of four general groups, the composition of each one being shown by the following tabular summary.

AVERAGE COMPOSITION AND RANGE OF COMPOSITION OF SIGNIFICANT GROUPS

| *Depth from Surface, in Feet* | *Percentage of Ferromagnesian and Other Heavy Minerals* | | *Percentage of Quartz* | | *Percentage of Feldspar* | |
|---|---|---|---|---|---|---|
| | *Average* | *Range* | *Average* | *Range* | *Average* | *Range* |
| 3,800–3,840 | 0.3 | 0.1– 0.8 | 99.7 | 98.6-99.9 | Trace | 0 – 0.5 |
| 3,845–3,975 | 4.8 | 1.4–12.6 | 44.1 | 30.4–61.3 | 51.1 | 34.6–64.3 |
| 3,980–4,070 | 26.9 | 4.6–69.0 | 32.7 | 17.2–46.1 | 40.4 | 8.4–66.9 |
| 4,075–4,250 | 53.4 | 15.5–69.1 | 25.6 | 17.8–42.8 | 21.0 | 8.7–59.1 |

It will be noted that the percentage of ferromagnesian minerals increases markedly with increasing depth, that the percentages of quartz and feldspar both decrease with increasing depth, and that these changes take place rather abruptly at the horizons indicated.

Furthermore, there is a considerable range in the percentages of ferromagnesian minerals, quartz, and feldspar below 3,840 feet, both of the latter varying, in general, inversely with the amount of ferromagnesian minerals, present, this variation being especially noticeable in the case of feldspar.

### CONTACT BETWEEN CAMBRIAN AND PRE-CAMBRIAN

The first marked change in mineral content, occurring between 3,840 and 3,845 feet, indicates the contact between Cambrian sandstone and pre-Cambrian gneiss. This change is shown not only by the decrease in quartz and the increase in feldspar and ferromagnesian minerals, but also by the presence of accessory minerals and ferromagnesian minerals not observed in samples from higher elevations, and by the character of all minerals present. In samples above 3,845 feet, quartz is in well rounded grains, whereas at 3,845 feet and below both quartz and feldspar are in angular fragments. Moreover, above 3,845 feet the heavy minerals are chiefly zircon, garnet, and magnetite, with traces of rutile and tourmaline, all of which are well rounded and rarely show any crystal faces, whereas at 3,845 feet and below, biotite and apatite are present also, the percentages of zircon and garnet increase considerably, and the minerals are not eroded but are well crystallized, the apatite in somewhat globular crystals, in part, but the zircon in beautiful, well formed, unscratched crystals with sharp pyramidal terminations and some faces showing lines of zonal growth, indicating conclusively that they have not been eroded but have been merely separated from the enclosing gneiss during drilling. The absence of biotite and apatitie above 3,840 feet is also significant. There seems little doubt, therefore, that the contact between Cambrian and pre-Cambrian rocks is at a depth of 3,840–3,845 feet below the surface, or at an elevation of 2,920–2,925 feet below sea-level. Moreover, the contact apparently is not gradational but is a very sharp one, almost pure quartz sandstone passing into granitic gneiss within a few feet.

### PRE-CAMBRIAN GNEISS COMPLEX

The pre-Cambrian rock on which Cambrian sandstone is resting in the Vance well has the characteristics of a gneiss. This is well shown by the mineral variation from sample to sample and also by some large fragments recovered from the well, which show typical gneissic banding. The upper part of this gneiss, between 3,845 and 3,975 feet, is typically granitic. However, below that depth the character is more variable. Between 3,975 and 4,070 feet, granitic bands alternate with

those rich in ferromagnesian minerals, and below 4,070 feet the more basic bands predominate and the rock has the characteristics of a hornblende gneiss. Considered in its entirety, therefore, the pre-Cambrian section of the Vance well apparently constitutes a gneiss complex.

The minerals composing the various bands of this gneiss show some interesting relationships. It has been shown that plagioclase is present in those bands containing the larger amounts of ferromagnesian minerals, the plagioclase varying in composition from the more sodic varieties to those almost as calcic as labradorite, the more calcic types being especially associated with hornblende. Microcline is characteristic of bands containing small amounts of ferromagnesian minerals, and is the chief feldspar of such bands. However, microcline is present in some quantity, also, in those bands containing plagioclase, and quartz is conspicuously present in the more basic phases.

These mineral relationships may furnish some clue to the possible origin of the gneiss complex. There can be little question that the association of minerals characteristic of the more basic part of this section, in the amounts shown, is not indicative of any normal igneous rock. Moreover, it is difficult to postulate a sediment which would yield such a rock as a result of metamorphism, although the contact metamorphism of certain impure quartzitic sediments intruded by granite is a possibility. A more logical possibility, however, would be the complex resulting from the intrusion of intermediate to basic igneous rock by granite. This could easily explain the association of biotite, hornblende, plagioclase, microcline, and quartz, in the quantities present, the microcline and quartz being injected as granitic magma, the hornblende and plagioclase being present in the more basic igneous rock or, in part at least, developing during metamorphism of such rock. Moreover, the accessory minerals zircon, apatite, and garnet are easily explained in this case, as zircon and apatite are characteristic accessory minerals of granite, and garnet is a common metamorphic mineral. Consequently, it appears that the most logical explanation of the origin of this pre-Cambrian gneiss complex is obtained by postulating that an intermediate to basic igneous rock was intruded by granitic magma.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 24, NO. 4 (APRIL, 1940), PP. 693-700, 1 FIG.

# DEPOSITION OF LISSIE AND BEAUMONT FORMATIONS OF GULF COAST OF TEXAS[1]

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## ABSTRACT

The Lissie formation was deposited on a peneplaned surface. Later action of major streams produced a series of alluvial plains near the coast on which the later phases of the Lissie and the Beaumont were deposited under a flood-plain environment. The Beaumont was a continuation of the same cycle of deposition by a series of distributaries on a plain of very low relief. The physical evidence left by this sequence of events is believed to contribute much to a better understanding of the deposition of earlier land deposits of the Gulf Coast.

## INTRODUCTION

During the early part of 1939 this brief paper was submitted to a study group of the Houston Geological Society, who were making a study of Gulf Coast sediments because it was felt that the transportation and deposition of the Lissie and Beaumont sediments represented a definite cycle of sedimentation which has continued to the present, and some of its effects may still be seen and studied on the surface of the coastal plain. It was suggested that a study of the conditions and sequence of events which attended the deposition of this series would throw much light on conditions under which the earlier sediments of the coastal plain were deposited.

There is an abundance of subsurface data from wells which have been drilled along the coastal area. The marine phases of these sediments are easily correlated but the non-marine, or landward phases, inject much confusion into the interpretation of the stratigraphic section. While it is realized that this later deposition of the Lissie and Beaumont is much restricted as compared to the width of land deposits of some of the earlier formations, the conditions under which deposition occurred must have been very similar. It is reasonable to believe that the gradual subsidence of the coastal area continued throughout the deposition of all these sediments and to the present time. With the source material from similar areas, and assuming that the land mass on the northwest maintained a fairly constant level, there is every reason to believe that the zone of deposition along the coastal plain has maintained a fairly constant set of conditions which will find their counterpart in the Lissie and Beaumont plain. A close study, therefore, of some of the physiographic conditions and the dis-

[1] Manuscript received, September 13, 1939.

[2] District geologist, The Ohio Oil Company.

tribution of the sediments over this relatively undisturbed plain, should give some insight into conditions existing during the deposition of the non-marine beds during earlier cycles of sedimentation from Eocene deposits to the present time.

The Lissie and Beaumont formations are considered together because they form an integral part of a single cycle of sedimentation. This cycle began with the rejuvenation of coastal-plain streams and the deposition of the coarse, poorly sorted material of the Lissie. As the cycle progressed, finer materials were supplied to form the Beaumont clays and finer sands of the Beaumont stages. Each of the stages of this process from the time the Lissie was swept down across a peneplaned surface to the present flood-plain effects of the modern streams, some physiographic markings have been left to give evidence of the changes that were taking place. It is the purpose of this paper to trace some of these physiographic changes produced by the shifting stream pattern and the resultant distribution of the different types of sediments on the land and the bordering coastal fringe.

ACKNOWLEDGMENTS

The writer is indebted to Coe S. Mills, who did much of the surface work along the Beaumont plain, and to The Ohio Oil Company, for permission to publish this material.

## PRE-LISSIE PLAIN

The interior limits of the Lissie outcrop along the coastal plain are, everywhere, resting on beds of Fleming age. The presence of an unconformity at the base of the Lissie has long been recognized and is readily discerned by the decided change in lithologic character of the formations. However, the writer is of the opinion that the time interval represented between the Fleming beds cropping out at the base of the Lissie and the latter formation is longer than generally realized. It is believed 't may have represented several cycles of sedimentation and coastal-plain deposits, which have been widespread but were later eroded until only their wedge-shaped edges have been covered by later deposition and are now unexposed in the subsurface of the near coastal counties. It is this section of rocks, encountered in wells near the coast, that have led some estimates of very considerable thickness of the Lissie sands and Beaumont clay. Observation of many shallow borings on both the Lissie and Beaumont plain have led to the conclusion that the Lissie and Beaumont beds are a comparatively thin group, and, in the Gulf coast sedimentary column represent only a very short time interval. They form a thin veneer over the lower

coastal area, but if erosion continues the inland portions of the strata will be removed and, like previous cycles, will form a wedge-shaped remnant near the coast, where they would form such a slight portion of the stratigraphic column and be so irregularly bedded as to be unrecognized as a unit.

Previous to the deposition of the Lissie a period of quiescence and erosion had reduced the coastal area to a peneplain. This condition is indicated by: (1) uniformity of the surface on which the Lissie was deposited; (2) the consistently uniform thickness of the Lissie on the uneroded parts of the Lissie plain; (3) the abundance of poorly sorted, highly ferruginous material in the Lissie indicating a long period of deep weathering prior to the coastward tilting, which produced the beginning of the cycle; and (4) the comparatively even distribution of the Lissie gravel, sand, and clay, with little sorting, indicating its distribution by many small streams over a flat plain rather than by large entrenched drainage systems, which would have sorted the material and provided a very different sedimentary unit. This peneplanation is believed to have developed well into the interior, at least as far as the Edwards Plateau and the Claiborne areas of northeast Texas and northern Louisiana, whence much of the gravel and ferruginous material was derived.

### LISSIE DEPOSITION

The early phase of the Lissie deposition was apparently initiated by a sudden flexing of the coastal area which produced an even sheet of gravel, sand, sandy clay, and much ferruginous material in the form of concretionary nodules and cementing material. The most striking characteristics of this material are its ferruginous content, its lack of sorting during the depositional process, and the uniformity of thickness of this deposit over great distances along the coast. Its thickness is commonly placed at 70 to 80 feet.

This sheet doubtless existed much farther inland than its present outcrop, as still coarser material. It is suggested that the gravels, occupying the higher divides in the areas adjacent to the Edwards Plateau and sometimes referred to as Uvalde gravel, may have been closely associated with this phase of deposition.

The second phase of the cycle began when the streams started to intrench themselves into this plain, and to erode and transport the interior portions of the Lissie toward the coast. This process gradually developed channels which cut deeper into the updip phases of the Lissie and into older formations. That slight tilting coastward occurred during this process is attested by the series of terraces along

all of the major streams which developed during periods of quiescence to be later channelled by rejuvenation of the streams. The earliest terraces were more widespread, and in some areas, formed wide stretches of gravel and sand deposits which are only slightly lower than the former position of the Lissie. The lower and later terraces became more and more restricted in area, but they exist today along all of the major streams in the coastal area. Those terraces along streams which passed through the Edwards Plateau area have great quantities of coarse, quartzitic gravel in them. At least a part of this gravel is believed to have been reworked material from the original Uvalde gravel deposits.

During this period of intrenchment of the major streams, the material eroded from the interior area was transported and re-deposited nearer the coast. This process of transportation and deposition built a very flat near-coastal, alluvial plain, in which the material was predominantly sand but considerably better sorted than the earlier Lissie deposits. However, as the streams cut deeper into the interior areas, finer materials began to be supplied and the near-coastal phases of the Lissie obtained some of the finer sediments to form thin clay lenses within the sandy zone.

Thus, at the close of the Lissie deposition, much of the material from this formation had been eroded and redeposited by a period of stream action which had probably involved this material in many movements coastward. At the end of this phase the streams had cut somewhat deeply into the formations of the interior and flowed from these entrenched areas onto a very flat, sandy, low-gradient plain, which bordered the coast and covered the area which corresponds very closely to that of the present Beaumont plain. The streams on this plain were doubtless sluggish, and sand clogged and broke over into many distributaries to form broad, flat alluvial plains which coalesced with similar deposits of other streams. Conditions along the coastal fringe were favorable for wave and wind action to form beach ridges which later gentle submergence would turn into the present type of shore line.

### BEAUMONT DEPOSITION

The change from later Lissie deposition to the Beaumont was merely a change to finer sediments brought down by the major streams from the interior. These streams had entrenched themselves through the inner part of the coastal area, the rapid eroding process was ended, and more of the load of the streams was being supplied from farther inland. This material was finer, more calcareous where

it was supplied from the great Cretaceous areas on the northwest, and varying in texture with the differences in source rock throughout the drainage area of the many streams.

The Beaumont deposition may be divided into two phases. The first phase is that part of the sedimentation during the period in which the streams were building up their channels, producing distributaries, and migrating back and forth across the zone of influence of the stream. The second phase was initiated by coastward tilting, which changed the gradient of the Beaumont plain enough to accelerate the streams. This started a cutting process which changed aggrading to degrading channels.

The first phase of the Beaumont deposition represented the greater part of the time interval involved, and it was during this interval that the major part of the surface expressions of the physiographic province known as the Beaumont plain was given its present character. The gradient of the plain towards the coast is thought to have been very slight, perhaps less than half of its present slope of 2 feet per mile, and the relief on the plain was very slight and confined largely to stream levees, and remnants of stream levees left by abandoned channels. During flood stages, the streams probably covered wide areas, much wider areas than present day streams. They clogged their channels and broke over into many distributaries to form a constantly shifting stream pattern. During this process the interstream areas were being covered during flood stages by muddy, quiet waters which deposited fine silts and clay while the coarser material was being deposited along the channels to form low levees and channel fill.

Figure 1 was drawn for the purpose of showing the distribution of different types of sediments over this coastal plain by two typical streams, the Colorado and Brazos rivers, during this early Beaumont stage. The pattern of distribution shown on the surface probably represents only the work of streams in the closing part of this phase. The distribution of sand and sandy clays in long linear areas, radiating from the vicinity where the stream enters the plain, implies the position of former channels of these rivers. These sand and sandy clay areas almost invariably occupy a slightly higher elevation than the surrounding Beaumont clay, and represent levee and near-channel deposits. In a few localities remnants of old stream channels may still be detected, although these seem to melt down and rapidly disappear under the influence of localized erosion by rainfall and wind action. Fairly distinct abandoned channels of the Colorado River may be seen about 3 miles southwest of the town of El Campo, in Wharton County, and in several localities north of that town. Faint remnants

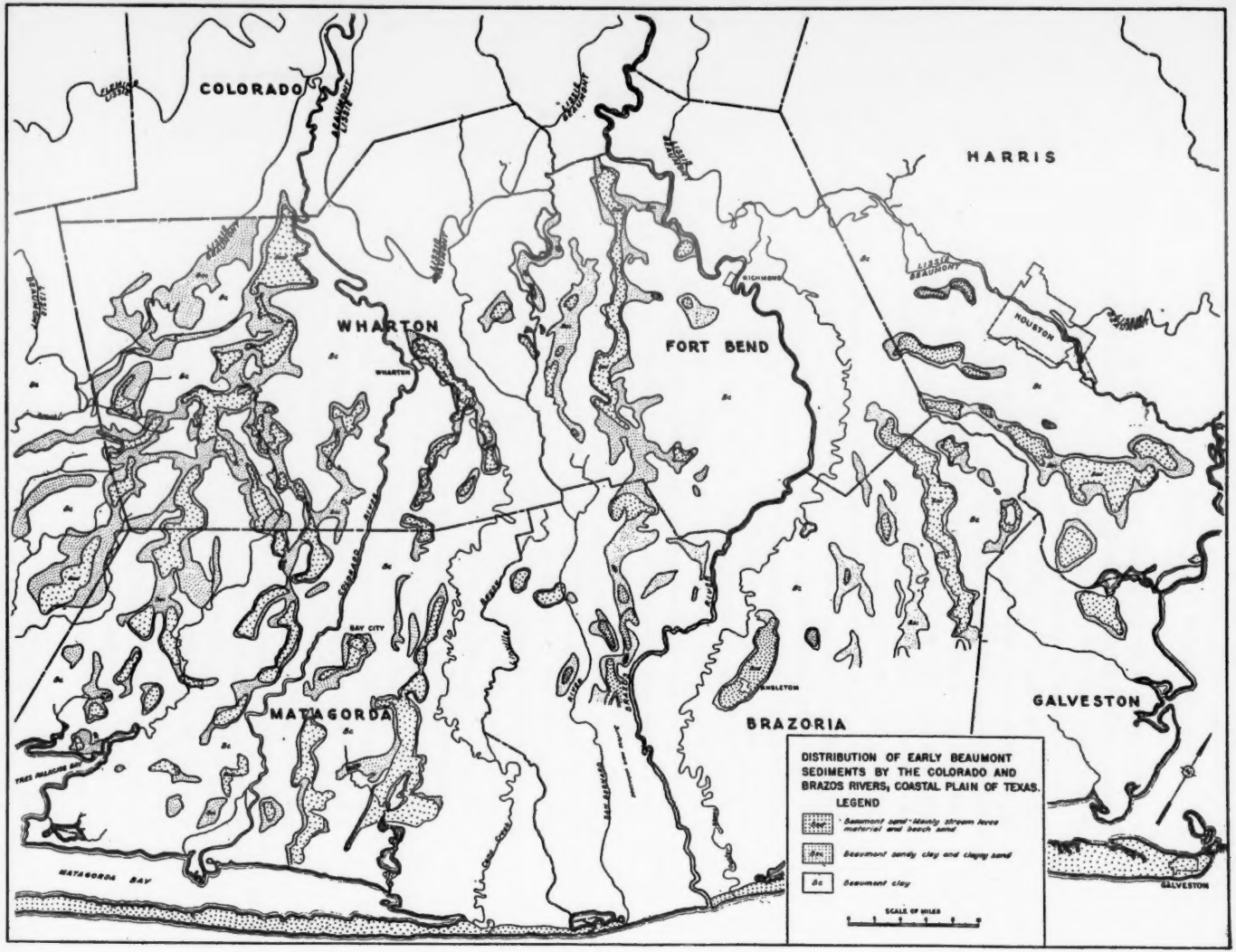
COLORADO
HARRIS
WHARTON
FORT BEND
MATAGORDA
BRAZORIA
GALVESTON
HOUSTON
RICHMOND
WHARTON
BAY CITY
ANGLETON
GALVESTON
MATAGORDA BAY
DISTRIBUTION OF EARLY BEAUMONT SEDIMENTS BY THE COLORADO AND BRAZOS RIVERS, COASTAL PLAIN OF TEXAS.
LEGEND
Beaumont sand - Mostly stream levee material and beach sand
Beaumont sandy clay and clayey sand
Beaumont clay
SCALE OF MILES

FIG. 1

may be seen about 2 miles northwest of the town of Midfield, in northwestern Matagorda County. One of the more distinct channels of this time interval, made by the Brazos River, occurs along the sandy area extending from Fresno in eastern Fort Bend County, to the town of Alvin in Brazoria County. Similar meanders of old channels may be seen in the area just north of Angleton in Brazoria County and somewhat fainter traces may be noted between Beasley and Needville in Fort Bend County. Strikingly prominent remnants of channels formed by the Trinity River have been noted in Jefferson and eastern Chambers County where that river seems to have spent much of its energy during part of this early Beaumont stage.

The Rio Grande and Nueces rivers shaped physiographic plains similar to the Colorado, the Brazos, and the Trinity, and their sedimentary history was similar. However, the drainage area of the Rio Grande was more extensive and it was therefore capable of exerting more influence during flood stages. The smaller streams flowing across the coast, such as the San Antonio, the Guadalupe, and the Neches rivers, exerted much less influence but each played a definite part in the deposition of the Beaumont and the shaping of the physiographic plain on which it was distributed.

The second phase of the Beaumont deposition began with quickening of stream activity produced probably by a gentle subsidence in the coastal area. This increased the coastward slope of the Beaumont plain to its present position and gave the streams the velocity to start the cutting of channels across the plain. This produced a much restricted zone of influence for each of the streams and as they cut lower, their flood plains have narrowed to their present limits. The subsidence which started this change also drowned some of the coastal fringe and beach ridges became offshore islands or long, narrow peninsulas parallel to the coast. The greater part of the streams were then flowing into embayments inside the offshore fringe.

The influence of all the streams during this recent stage is well illustrated by those shown in Figure 1. The Colorado River confined its influence principally to a narrow belt in the area now occupied by the lower reaches of the Bernard River, Linville Bayou, Caney Creek, and several other old abandoned channels. All of these channels are thought to be former beds of the Colorado. While it was exerting its influence over this belt, the stream was building out delta deposits into the drowned areas inside the offshore island, gradually extending the mouth of the stream across the embayment, and finally flowing directly into the gulf. The Colorado River is thought to have occupied its present course only a few hundred years, yet this delta-building

process shown at the mouth of the stream in Matagorda Bay is strikingly developed.

The Brazos River influence first narrowed to a zone of less than 10 miles in width and later to its present flood plain which is much less. The earlier part of this process was over the zone along Oyster Bayou and closely paralleling the present stream which formed a flood plain definitely lower than the early Beaumont. During the formation of this plain the river shifted its course repeatedly, leaving oxbow lakes and undrained areas formed by the natural damming process of levee building. At the mouth of the stream it filled in the embayment area to extend its channels to the Gulf of Mexico just as the Colorado was doing farther west.

## CONCLUSION

However profound the changes may have been prior to the deposition of the Lissie, it is the writer's belief that the sequence of physiographic and sedimentary changes which occurred during the deposition of the Lissie and Beaumont were very slight and that these formations form only a comparatively thin portion of the sedimentary column of the Gulf Coast. Perhaps the most striking phenomenon of the entire process is the constant movement of sediments coastward by shifting stream channels, a constant loading of the streams from the upper reaches of the formations, and deposition of this load nearer the coast or beyond the coast. This lack of stability of deposition has the effect of beveling the inland portions of the formation and thinning or entirely removing it to carry it downstream to add to the thickness of this formation near the coast. The process of reworking the material many times, the transportation and redeposition of it, principally during flood stages, by constantly shifting streams, has produced a series of rocks that have little continuity of bedding.

All of the land deposits of the coastal area have the common characteristics of being thinner in the inland phases and thickening notably toward the coast. During the early stages of the Gulf Coast subsidence there was lower relief between the inland sources of the stream load and the depositional plain. This produced a wider zone for stream action, a slower development of the plain, and since less relief occurred, less thickening coastward resulted after the cycle had reached its conclusion. The materials that went into the early Eocene deposits of the coastal plain were probably supplied by major streams from a wide area on the northwest from which the sea had just receded. As the shifting of sediments southeastward continued, streams over the Cretaceous plain formed more relief, increased their areal extent, and thus increased their effectiveness.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
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# SPARTA-WILCOX TREND, TEXAS AND LOUISIANA[1]

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Houston, Texas

## ABSTRACT

The major portion of this recently revived productive trend in the lower Eocene of the upper Gulf Coast of Texas and Louisiana is considered to lie between the −5,000-foot contour on the north and the −10,000-foot contour on the south. Sand conditions are such that this trend may be comparable in productive possibilities with the other major producing trends of the Gulf Coast.

The sands of the Cook Mountain formation and Wilcox group have come into recent and increasing importance as oil reservoirs. The purpose of this paper is to sketch briefly our present knowledge of this portion of the Eocene, to point out the possibilities, and to suggest some of the problems of the productive zone. It is hoped that this will prove informative to those not acquainted with the Sparta-Wilcox trend, and that it will provoke comment from those more familiar with the facts than the writers.

## INTRODUCTION

By way of background, the Sparta is the lower member of the Cook Mountain formation of the lower Claiborne group of Eocene age. It is named for a type locality in Bienville Parish, northern Louisiana. The Sparta is of continental origin and at its outcrop consists of 75 per cent sand and 25 per cent sandy shale. It thickens southeasterly into Louisiana and thins southwesterly into Texas so that it varies in thickness between 250 and 800 feet. It changes to shale very rapidly below its 5,000-foot level on the Texas side, but persists as a prominent sand body down to about its 9,000-foot level on the Louisiana side.

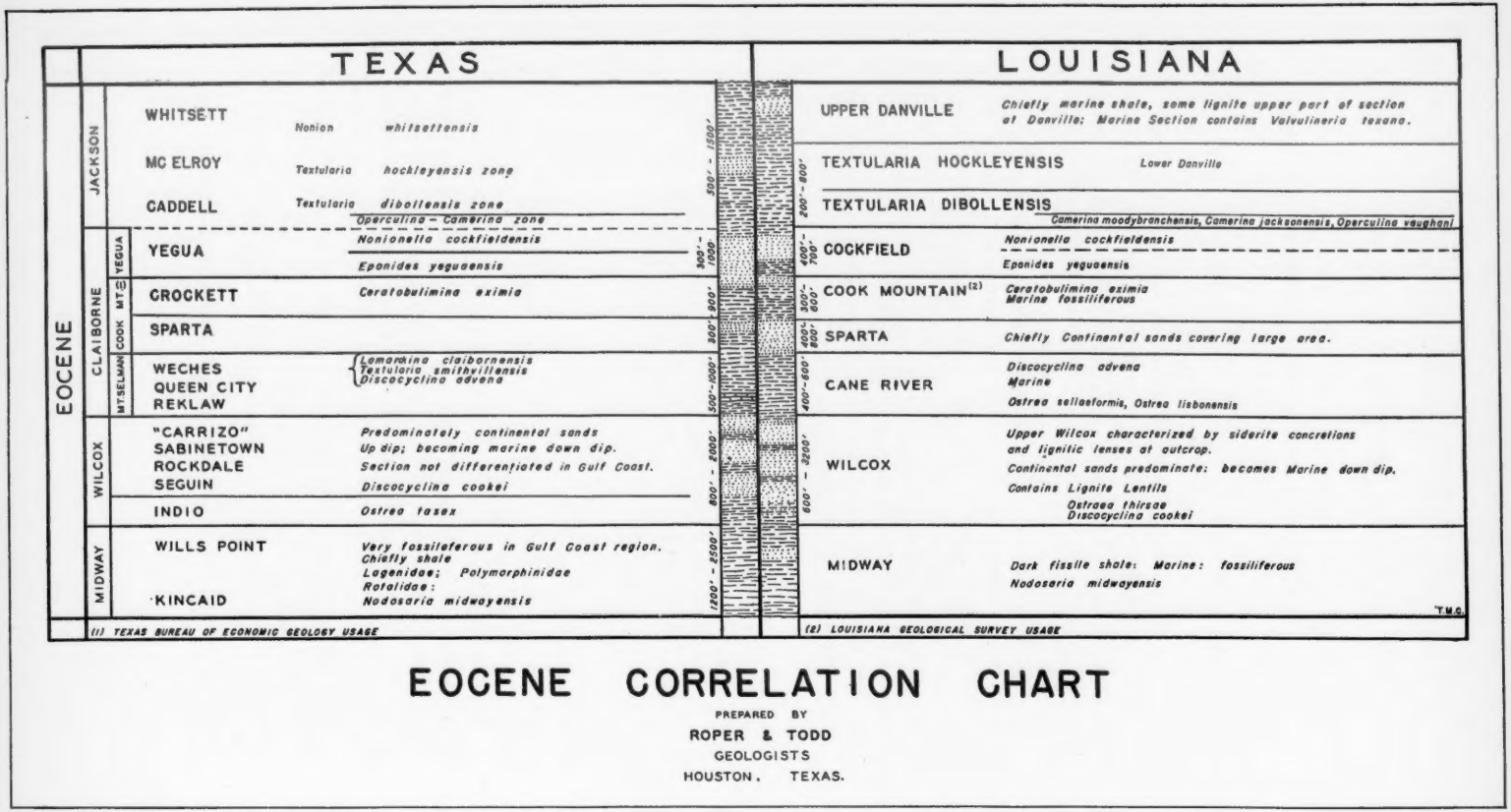
The Wilcox comprises a thick series of sands and shales, named for a type locality in Alabama. Wells in central Louisiana have penetrated as much as 3,000 feet of rocks belonging to this formation, and a well in Mississippi encountered in excess of 5,000 feet of Wilcox formations.[3] On the Texas side it has been subdivided[4] into the Sabine-

[1] Presented before Houston Geological Society, January 19, 1939, and before the Association at Oklahoma City on March 24, 1939.

[2] Consulting geologists, 527 Esperson Building.

[3] Phillips Petroleum Corporation, Newman Lumber Company No. 1, Perry Co., Miss.

[4] *Univ. Texas Bur. Econ. Geol. Bull. 3232* (1932), p. 571 *et seq.*, p. 651 *et seq.*, and references there cited.




# EOCENE CORRELATION CHART

PREPARED BY
ROPER & TODD
GEOLOGISTS
HOUSTON, TEXAS.

FIG. 1.—Eocene correlation chart, Sparta-Wilcox trend.

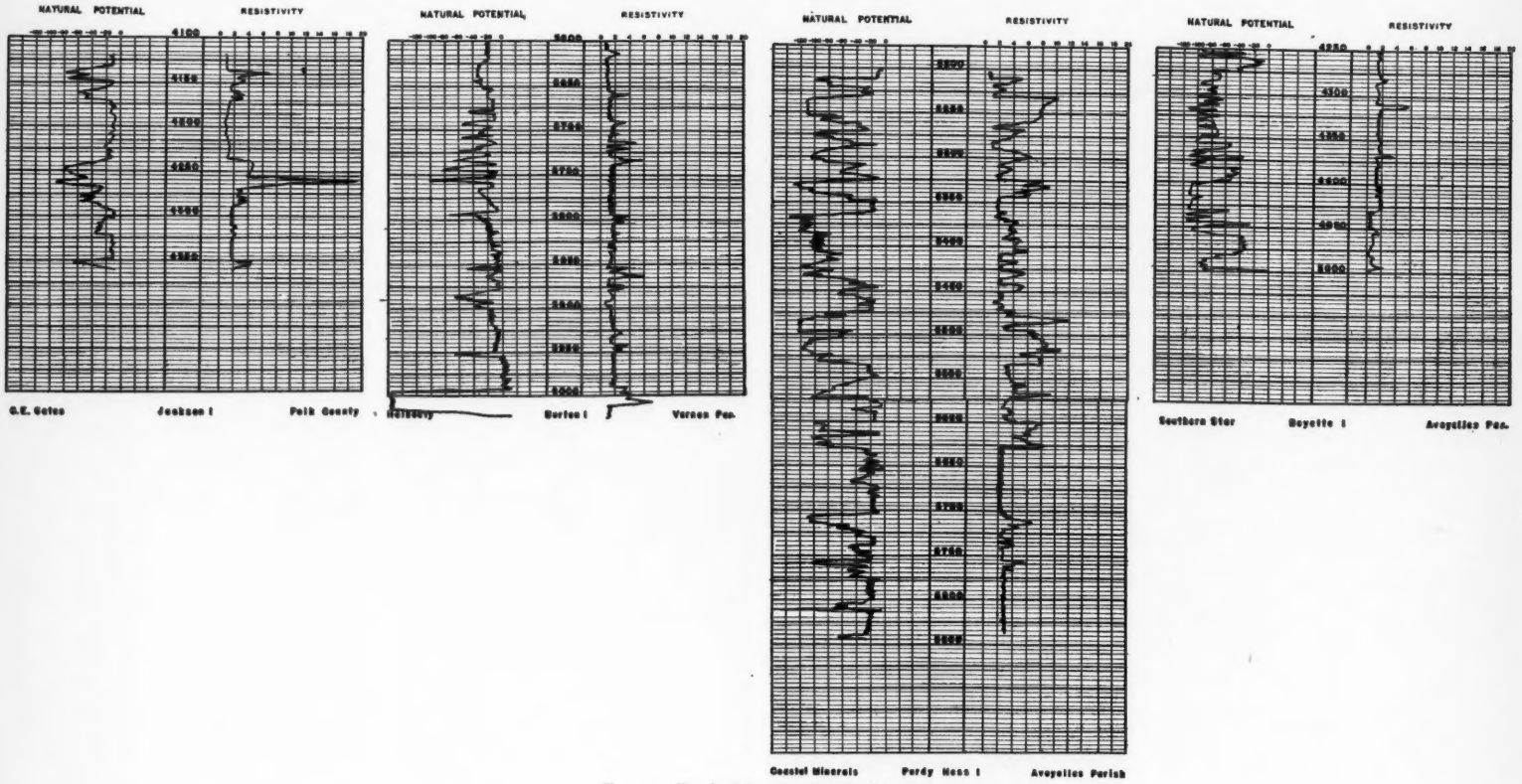



FIG. 2.—Typical Sparta electrical logs.

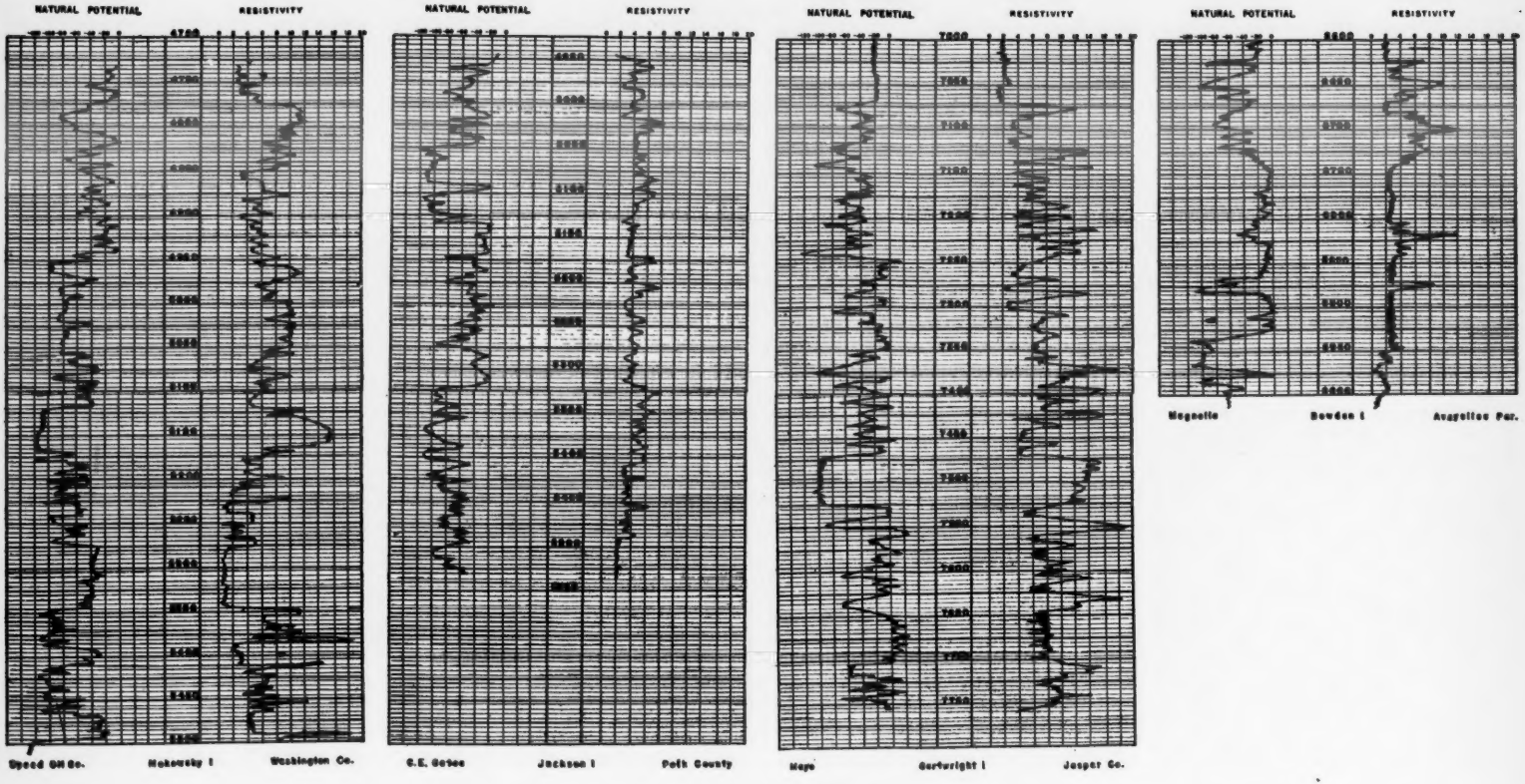



FIG. 3.—Typical Wilcox electrical logs.

town, Rockdale, and Seguin formations, the upper or Sabinetown section being of chief interest at the present time. The sands of this formation are well developed and persist prominently down to the 9,000-foot level; below the 10,000-foot level these sands appear to change to shale more rapidly. This is indicated by the record of the Stanolind Oil and Gas Company's Freeman No. 1 in Waller County, Texas, and the Herton Oil Company's Thistlewaite No. 1 in St. Landry Parish, Louisiana. The Wilcox seems to be a good reservoir as far east as southern Mississippi,[5] and as far west as Goliad County, Texas.

Detailed information on the subsurface sand conditions of both the Sparta and Wilcox is scattered and meager at this time, because few wells have been carried to interesting depths in these formations.

## HISTORY

Historically, production from this part of the Eocene is very old. The oldest production in Texas, at Chireno in Nacogdoches County, comes from the Cook Mountain and the Weches. The Old Urania production in central Louisiana is from the contact of the Cane River and the Wilcox. The Clay Creek piercement-type dome, in Washington County, Texas, has been producing from the Sparta and the Wilcox since the late twenties. The Kittrell production in Houston County, Texas, is from the Carrizo.

However, all of these earlier discoveries were small, non-prolific fields that constituted a meager reward for the effort and expense of exploring the areas. The result was that this trend very early acquired a dismal reputation which was not dispelled for many years. With known sands extending for many miles downdip from the outcrop, there never was a reason why this area should not produce oil, but there was the known fact that it did not produce oil in satisfactory quantities. These barren early results long retarded the development of this trend.

## NEW INTEREST

In the past 2 years conditions have greatly changed, but the bad reputation has lingered on much longer than the facts warranted.

Recent statistics reveal that an unusually high percentage of the wells that have been carried to the Sparta and Wilcox have proved productive.

[5] Henry V. Howe, "Louisiana Petroleum Stratigraphy," *Oil and Gas Journal* (April 16, 1936), p. 98.

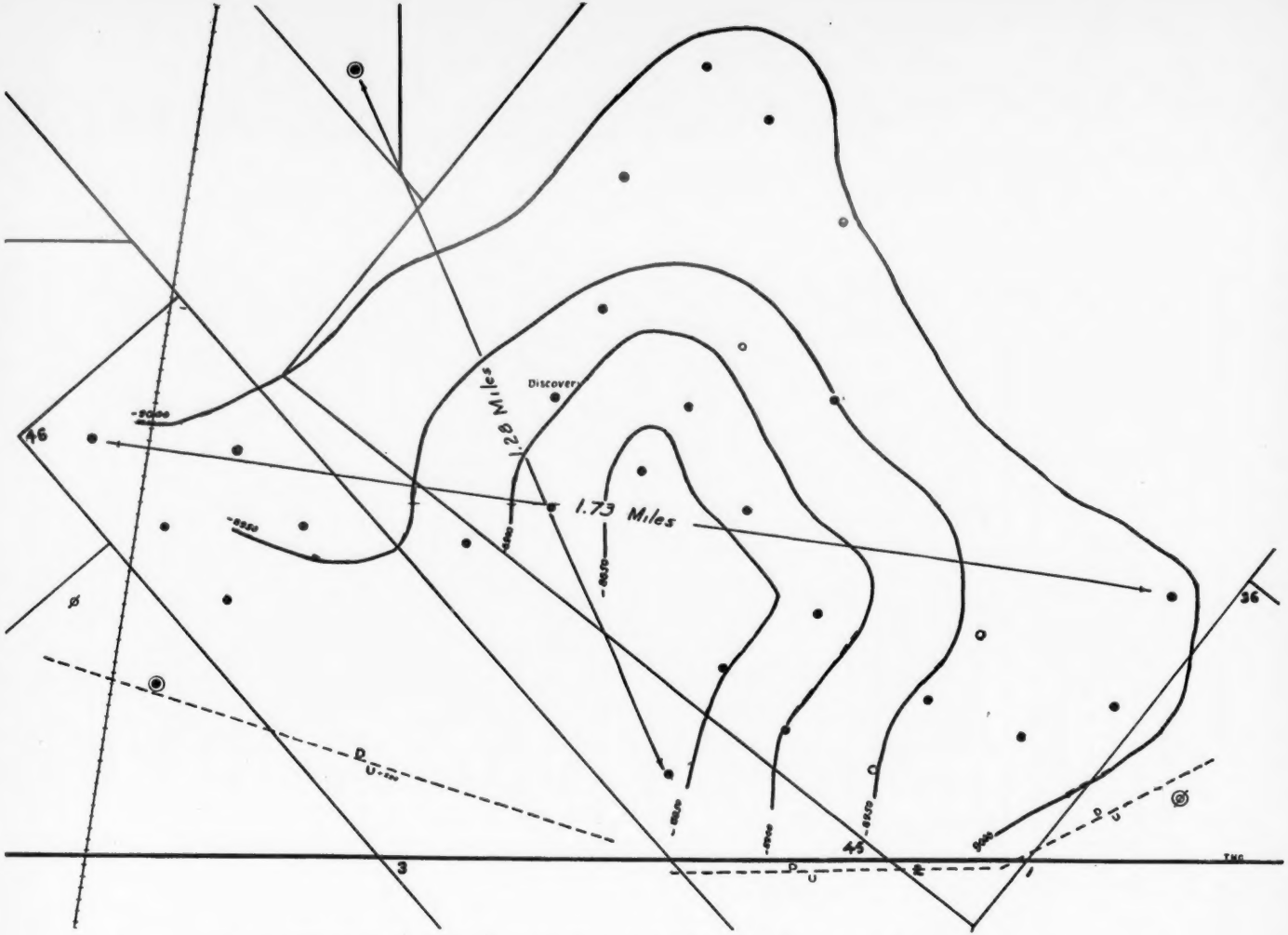



FIG. 4.—Ville Platte, Evangeline Parish, Louisiana, typical Sparta oil field. Contoured on top of Tate sand.

In several areas production has as yet been obtained from only one or a few wells, so that the full significance of the producing horizon in that field is not now known. This is the case at Segno, Cleveland, and Ace, where the Wilcox is now producing; and at Cheneyville, where one well produces from the Sparta sand. However, two fields have a sufficient number of wells to indicate that they will become first-class oil fields. These two fields are Joe's Lake in Tyler County, Texas, which is producing from the Wilcox, and which here is tentatively assumed to be a typical Wilcox field; the other is Ville Platte in Evangeline Parish, Louisiana, which produces from the Sparta and which is assumed to be a typical Sparta field.

### TYPICAL FIELDS

The Ville Platte field was discovered in September, 1937, and was the first Sparta production in Louisiana. Most of the present production is from the Sparta at 8,900 to 9,000 feet. The main producing sand body, called locally the Tate sand, is 60 feet thick; the upper 30 feet is an excellent reservoir, and the lower 30 feet is somewhat shaly. Another sand body, known as the Haas sand, lies immediately above the Tate sand. The Haas sand has a very large gas cap, and makes gas and distillate wells on top of the structure and makes oil wells only on the periphery. Considering only the Sparta possibilities, it now appears that between 2,000 and 2,500 acres will be proved productive and that the field has a reserve of 40,000,000 to 50,000,000 barrels. The Wilcox at Ville Platte is as yet not fully developed, although a few wells are producing from this formation; the Wilcox should greatly increase the area of the field and may double its reserve.

Joe's Lake was the first deep, prolific Wilcox production, and was discovered in May, 1937. The field lies entirely on the fee properties of the Republic Production Company and the Houston Oil Company, and since there have been no official releases of information by the operators, accurate data on the field are lacking. However, data available through the Railroad Commission, showing the location of the wells and giving their potentials, suffice to indicate that it probably will be a big oil field. It is believed to be producing from four Wilcox oil sands, at approximately the 7,600-foot level, which have an aggregate thickness of 200 feet. The field seems likely to cover 5,000 acres and is estimated to have a reserve of possibly 200,000,000 barrels; the Cockfield may also be proved productive and if so, will augment these figures. Ville Platte and Joe's Lake resemble each other in that both appear to be large flat structures.

FIG. 4.—Ville Platte, Evangeline Parish, Louisiana, typical Sparta oil field. Contoured on top of Tate sand.

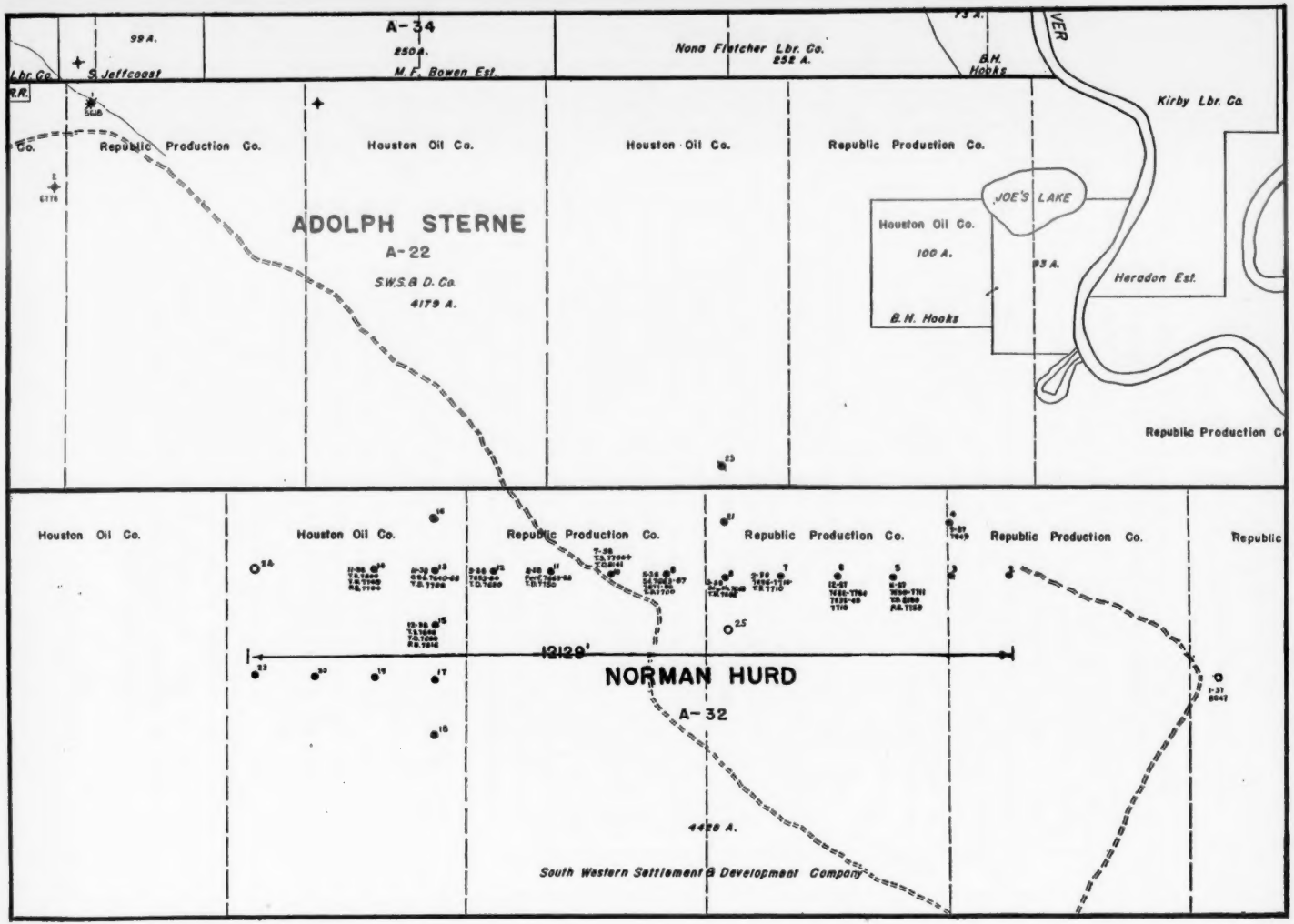



FIG. 5.—Joe's Lake, Tyler County, Texas, typical Wilcox oil field.

FIG. 5.—Joe's Lake, Tyler County, Texas, typical Wilcox oil field.

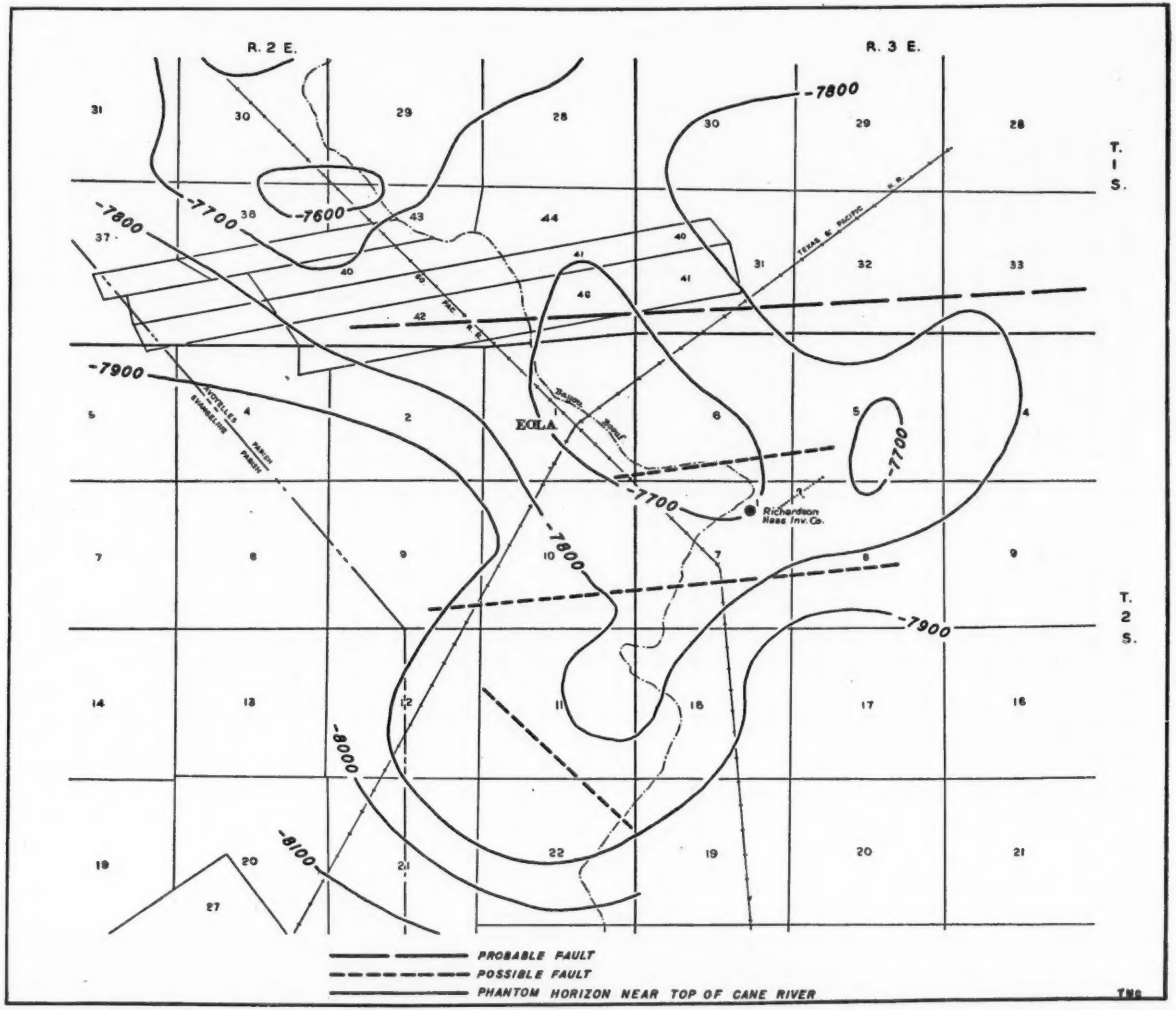



FIG. 6.—Reflection-seismograph structure map of Eola area, Avoyelles Parish, Louisiana.

The field of chief interest in the trend at this time is Eola, Avoyelles Parish, Louisiana, both because it is a new discovery and because it is experiencing a rapid development. The reflection seismograph map of the Eola structure on top of the Cane River, indicates a large flat structure similar to the other fields in the trend. The producing horizon is the top of the Wilcox, and from electrical log shows about 107 feet of producing section. In the present undefined state of the field, estimates on acreage and reserve are uncertain; but they are consistently large.

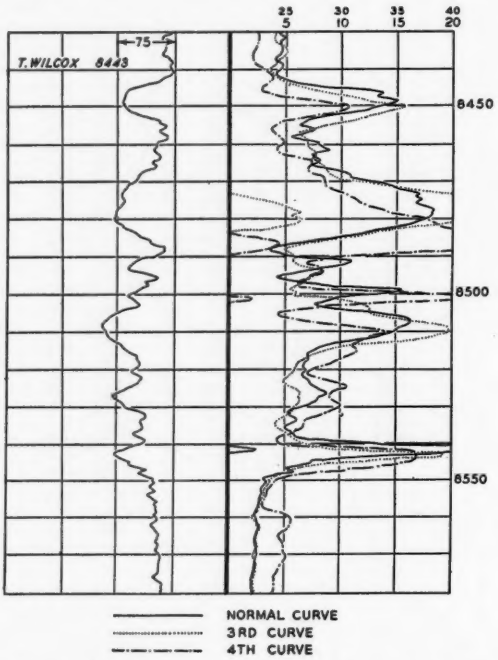



FIG. 7.—Electrical log, discovery well, Eola field, S. W. Richardson's Haas Investment Company No. 1, Avoyelles Parish, Louisiana.

## CORE ANALYSIS

The scientific development of the trend is being greatly abetted by the accurate and detailed analysis of the Sparta and Wilcox cores. Actual analysis, made at the well at the time the core is taken, of the Sparta and Wilcox sands have been made on a surprisingly large percentage of the wells drilled in the trend. The producing Sparta sands

show porosities averaging 18–20 per cent, permeabilities of about 400 millidarcys, pore saturation of 12–20 per cent, and probable recoveries (assuming water drive) of 400 to 600 barrels per foot acre. Wilcox producing sands show 20–22 per cent porosities, permeabilities around 300 millidarcys, pore saturation of 10–24 per cent, and probable recoveries of 500 to 750 barrels per foot acre, assuming effective water drive.

The photomicrograph[6] of typical Sparta sand is from the Continental Oil Company's Louisiana Central Land Company No. 2 at 9,075 feet in the Ville Platte field. According to the coregraph[7] of this well, this core showed a porosity of 26 per cent, a permeability of 1,410 millidarcys, and a volumetric saturation of 3.64 per cent.

The photomicrograph[8] of typical Wilcox sand is from S. W. Richardson *et al.* Haas Investment Company No. 3 at 8,559 feet in the Eola field. According to the coregraph[9] on this well it had a porosity of 23 per cent, a permeability of 24 millidarcys, and a volumetric saturation of 2.53 per cent.

## SLOW DEVELOPMENT

So much for what has been found in the trend; now what of its future? Will there be more such fields, or will these be proved only a flash in the pan temporarily to brighten the trend? And if there are more fields in the trend why have they not been found before?

The unexpected strikes and intense present activity cause us to reexamine our conclusions, and to advance new reasons for old failures. We believe that a study of the history of this trend will reveal the following facts.

In the pre-geophysical days (prior to 1923) this area suffered by comparison with the coastal areas because subsurface structure does not conform to surface structure. Therefore early drilling of surface structures did not lead to the discovery of oil fields as had been the case in the coastal region. Whatever the reason may be, it is possible to map a closed surface structure and then drill a well on it without finding corroboration of similar structure below. Another handicap of the area was that in the early days the depth limit of wildcats was about 5,000 feet, and not much oil appears to exist in these formations above their 5,000-foot levels. The extensive sand outcrops of the Wil-

[6] By Fred W. Bates, paleontologist, Lafayette, Louisiana.

[7] Prepared by Core Laboratories Inc., Dallas, Texas.

[8] By Fred W. Bates, paleontologist, Lafayette, Louisiana.

[9] Prepared by Core Laboratories Inc., Dallas, Texas.

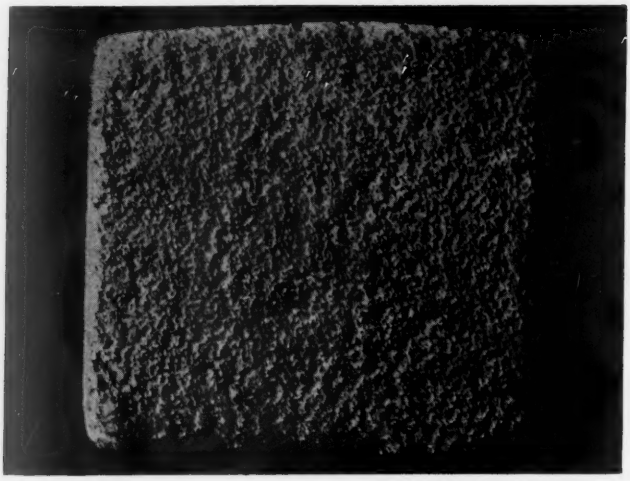


Fig. 8.—Photomicrograph of producing Sparta sand from 9,075 feet in Continental's Louisiana Central No. 2, Ville Platte field, Evangeline Parish, Louisiana. Porosity, 26 per cent; permeability, 1,410 millidarcys; saturation, 3.64 per cent.

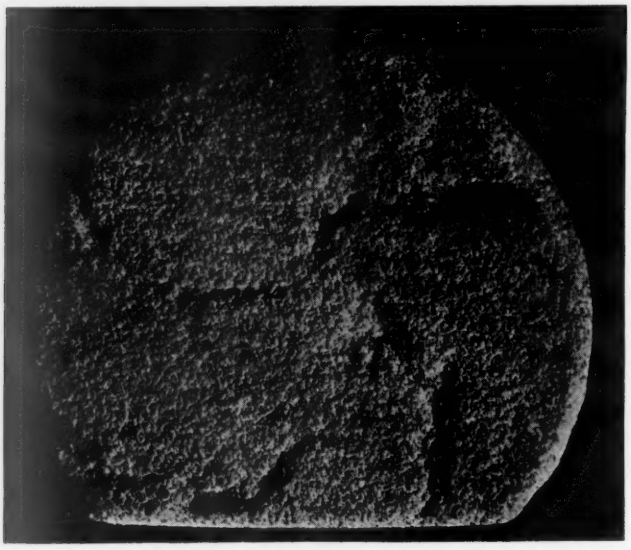


Fig. 9.—Photomicrograph of Wilcox sand from 8,559 feet in S. W. Richardson's Haas No. 3, Eola field, Avoyelles Parish, Louisiana. Porosity, 24 per cent; permeability, 28 millidarcys; saturation, 2.61 per cent.

cox and Sparta formations absorb so much meteoric water, that the formations have probably been flushed far down the dip. The contact between connate and meteoric water is expected to be variable due to faulting and pinching out around the Sabine uplift.

In the early geophysical days (1923 to 1930) this area suffered in comparison with the coast, since there were very few piercement-type domes for refraction seismographs to find, and because the torsion balance did not function well in the area because of rough terrain, wooded lands, and irregular subsurface structure.

The advent of the early reflection seismograph (1930 to 1935) did not help this trend much. It has always been a difficult area to work with reflection seismograph, because the type of structure present in the trend requires the closest and most accurate form of reflection-seismograph work. Such close and accurate work was not possible with early seismograph units and early technique.

Probably the greatest difficulty with reflection-seismograph work in the trend has been, and no doubt still is to-day, that not enough work has been done in the area to afford seismologists the experience necessary to solve the problems of the area. Real major regional shooting programs are just now getting under way in this trend, and practically all work done in the past has been spot shooting in hurried attempts to locate structures of coastal type, using coastal-type methods.

In recent years, with perfected types of shooting, we have learned that 5° dips and big closures are not needed to produce oil. We have learned that many of the flatter traps are preferable because they cover more area and suffer less from faulting. While this has been important in our thinking on the coast, it has revolutionized thought in the trend where the large, flat structures seems to be the only kind present, except for the rare salt domes.

In the trend we have learned that Joe's Lake, Segno, Bancroft, Ace, and Eola were all flat, unconvincing-looking structures and yet they all are fine oil fields to-day. The result is that we are coming to believe that very weak looking structures may possibly produce in this trend; and that no anomaly can be ignored, since existing fields have been found by drilling such flat anomalies. We also observe that the dilled closure ordinarily exceeds the reflected closure, so that when 50 feet of closure is mapped with reflection seismograph it is probable that 100 to 150 feet of closed structure actually exists.

## CONCLUSION

From their observation of the available evidence, the writers believe the following conclusions are justified at this time.

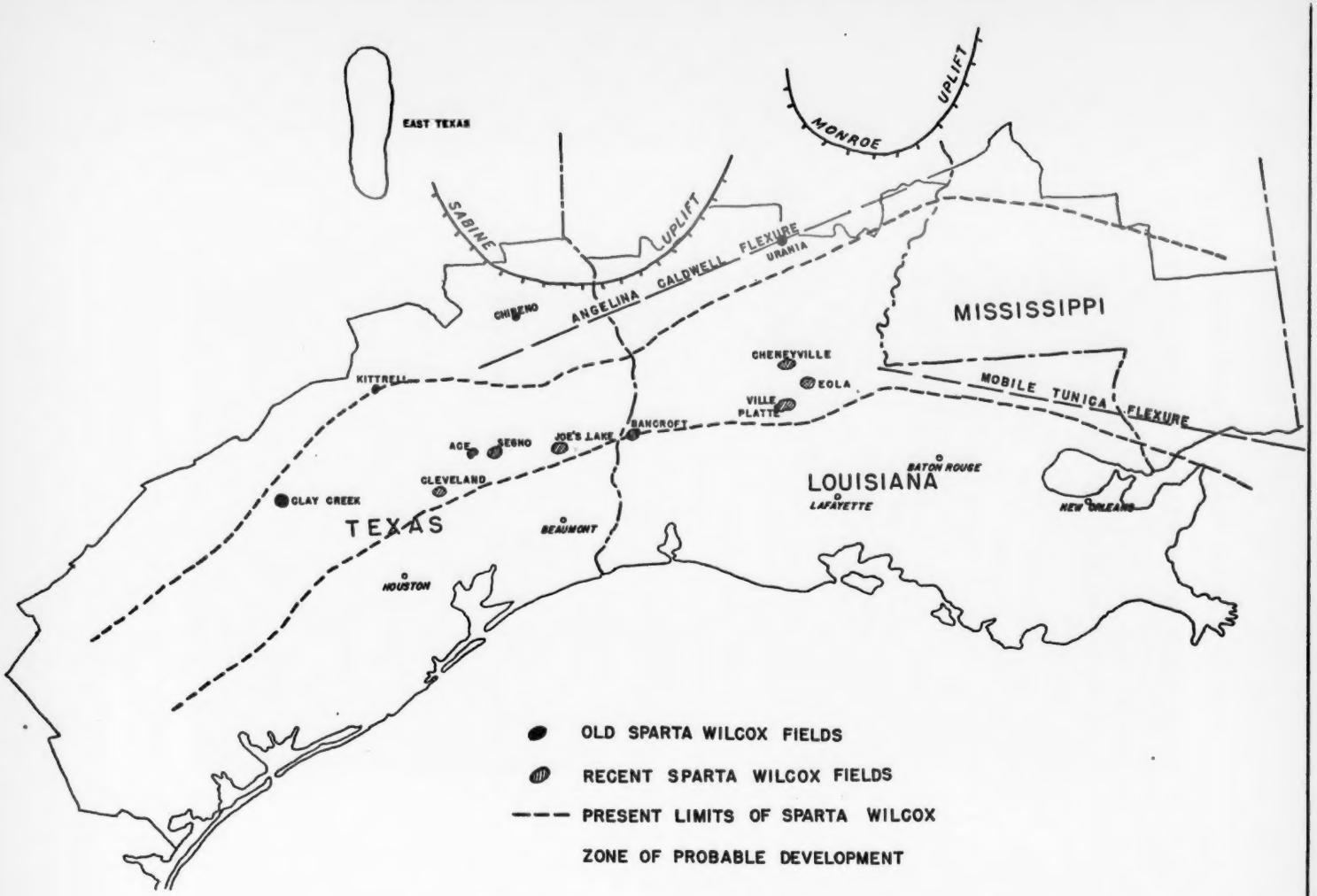



FIG. 10.—Sparta-Wilcox trend map; old and recent Sparta-Wilcox fields.

(1) Conditions are more favorable for the accumulation of oil in the Sparta and Wilcox sands between the 5,000-foot levels (where fresh water is present) and the 10,000-foot levels, where shale appears.

(2) Improved seismograph instruments, better shooting technique, new velocity curves and other improvements, coupled with a better understanding of the area, will result in making the seismograph as effective an instrument in the trend as it now is in the coastal region.

(3) The new gravimeters will work well in the trend, and will greatly help in rapidly and economically isolating the areas of probable structural deformation.

(4) Improved methods of soil analysis will assist in the locating of both structural and stratigraphic traps.

(5) Through the combined use of all of these new and improved methods the real effective exploration of this trend is just beginning.

There appears no reason to doubt that many more large, flat structures will be found, and it appears very likely that the ultimate producing area in the trend will rival that in the coastal region.

FIG. 10.—Sparta-Wilcox trend map; old and recent Sparta-Wilcox fields.

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# RESULTS OF RECENT FIELD STUDIES IN OSAGE, WASHINGTON, AND NOWATA COUNTIES, OKLAHOMA[1]

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Norman, Oklahoma

## ABSTRACT

The section studied and herein discussed comprises most of the Missouri subseries of the Pennsylvanian series. Its subdivision into two groups, the Skiatook below and the Ochelata above, is recognized.

The Seminole formation of the Stonewall Quadrangle is correlated with that part of the Coffeyville formation of Ohern lying between the top of the Lenapah limestone below and the base of the Checkerboard limestone above. The Checkerboard is raised to formation rank and the Coffeyville formation is correspondingly restricted. The Hogshooter limestone remains a formation and is expanded to include three members in the north part of the area and two in the area west of Tulsa. The Nellie Bly formation remains as originally defined. The Dewey limestone is equivalent to the Drum formation of Kansas but is absent immediately south of the Kansas-Oklahoma line, owing to pre-Chanute erosion.

The Chanute and Iola formations are mapped entirely across the area. The term Wann formation is revived and restricted. The Torpedo sandstone and overlying shale are extended both northward and southward from the type locality, but are found to be cut off at both extremities by pre-Birch Creek erosion. The Birch Creek limestone is identical with the Panther Creek limestone and probably equivalent to the Little Kaw limestone of the Kansas section. The Birch Creek rests upon the Wann formation, in the south part of the area, and overlaps, northward, the Torpedo sandstone and overlying shale, indicating an unconformity. Beds above the Birch Creek limestone in the extreme northwest part of Washington County are referred to the Weston shale of the Kansas section.

## INTRODUCTION

The investigation here reported was begun in August, 1937, as a study of phosphate and limestone deposits, in Washington County, in relation to their suitability for agricultural use. A further purpose was to secure such detailed information on the exposed rocks as would advance our knowledge of the geology of Oklahoma and facilitate more precise correlations of the beds exposed in Washington County with those in other areas of surface exposures, and with corresponding units found by drilling for oil and gas, in areas to the west. While the work was concerned primarily with Washington County, it was necessary, in order to embrace a workable geologic unit, to do considerable work in Osage County, to the west, and in Nowata County, to the east. In addition, it was also necessary to check and correlate, in the field, work previously done in Osage County by various geologists of the United States Geological Survey.[3]

[1] Manuscript received, November 28, 1939.

[2] Field geologist, Oklahoma Geological Survey.

[3] David White and others, "Structure and Oil and Gas Resources of the Osage Reservation, Oklahoma," *U. S. Geol. Survey Bull. 686* (1922).

Thanks are due to Norman D. Newell, who gave two days of his time for a field conference, and to Joseph L. Borden, for field assistance, two measured sections, and for the location of a hitherto un-

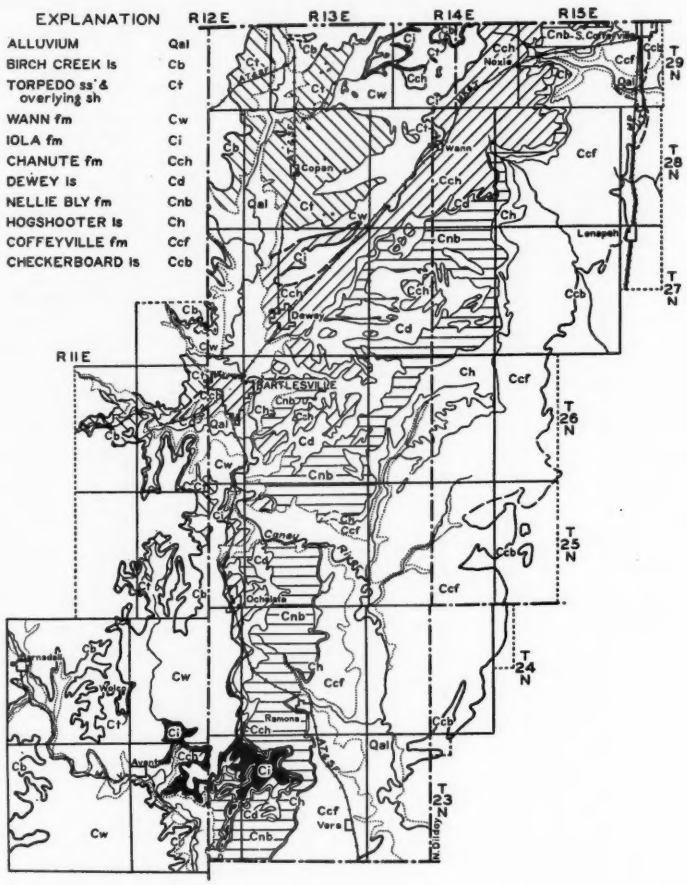


FIG. 1.—Areal geologic map of Washington County, and adjacent parts of Nowata and Osage counties, Oklahoma.

known outcrop of Hogshooter limestone southeast of Bartlesville. John R. Davis, then a graduate student of the University of Oklahoma, was a valuable assistant during the summer of 1938. Robert H. Dott has lent his assistance and encouragement throughout.

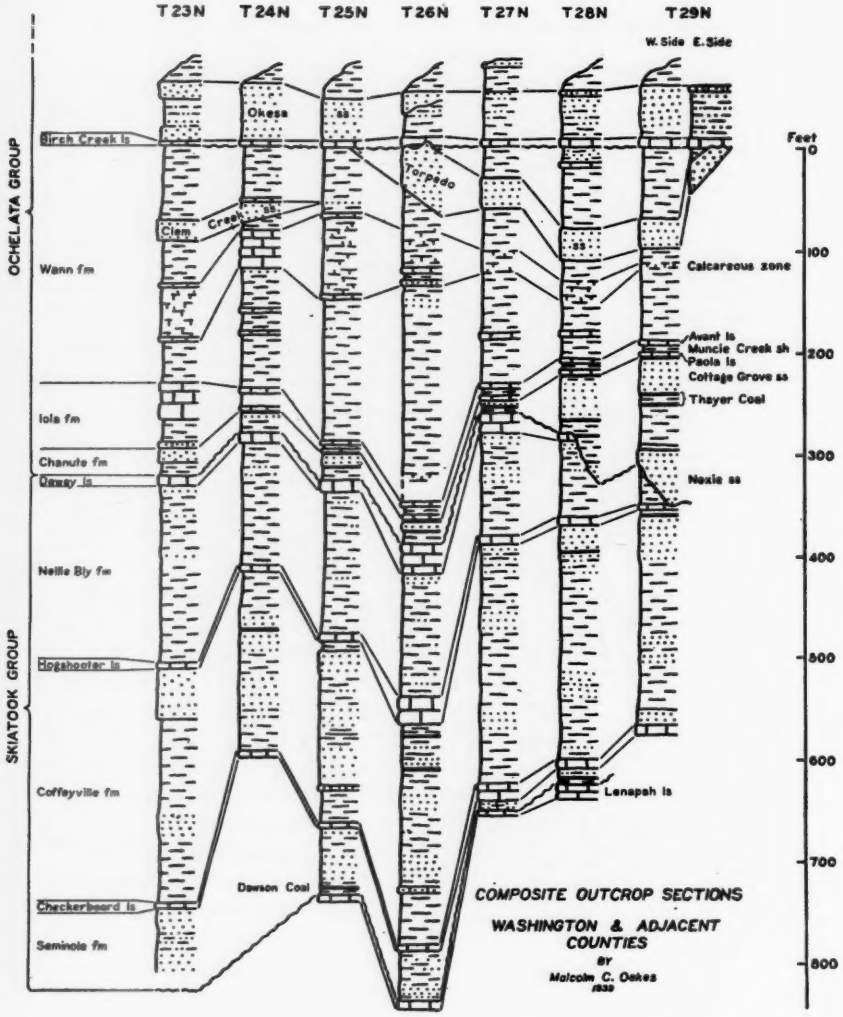


FIG. 2.—Measured outcrop sections of Pennsylvanian rocks exposed in Washington and parts of adjacent counties, Oklahoma.

### SURFACE STRATIGRAPHY

Rocks of middle Pennsylvanian age, belonging to the Missouri subseries, are exposed in this area and form a part of the sequence of upper Carboniferous rocks that is so well developed in the northern Mid-Continent area. In common with other parts of the northeast Oklahoma section, many individual beds continue with unbroken outcrops across the state line, from Kansas. Other Kansas units undergo complete change of facies before reaching the state line, so they are unrecognizable in Oklahoma. A sufficient number of Kansas units are present in northern Oklahoma to establish definite correlations, and to permit a broad classification that corresponds, in a general way, with the classification used in Kansas.

### MISSOURI SUBSERIES

The Missouri subseries is recognized as one of the four major subdivisions of the Pennsylvanian of Oklahoma and includes rocks of the same age as those that are similarly classified in Kansas. It is set off from the underlying Des Moines subseries by an unconformity and faunal change that have been observed from the Kansas-Oklahoma line to the area of the Arbuckle Mountains. Further work will doubtless demonstrate that it is separated from the overlying Virgil subseries by a large unconformity which is marked by changes in lithology and large-scale truncation of beds. Neither the basal nor the upper limits of the Missouri subseries are exposed in the area investigated, so the upper and lower boundaries were not studied in detail, and our knowledge of their relationships is based largely on the results of previous studies by other workers.[4,5]

Moore, Newell, Dott, and Borden[6] suggested a division of the Missouri rocks of northern Oklahoma and southern Kansas into two groups: Skiatook and Ochelata. The logic of this division, as applied to rocks exposed in the area covered by this study, has been fully demonstrated. In suggesting this division the application of Skiatook was

changed so that its lower boundary coincides with the disconformity that marks the base of the Missouri subseries, and its upper boundary is placed

[4] Robert H. Dott, unpublished manuscript.

[5] Raymond C. Moore and Norman D. Newell, "The Missouri-Virgil Boundary in Southern Kansas and Northern Oklahoma," *Kansas Geol. Soc. Guidebook*, Eleventh Annual Field Conference (1937), p. 37.

[6] Raymond C. Moore, Norman D. Newell, Robert H. Dott, and Joseph L. Borden, "Definition and Classification of the Missouri Subseries in Northeastern Oklahoma," *Kansas Geol. Soc. Guidebook*, Eleventh Annual Field Conference (1937), pp. 39–43.

TABLE I

SUBDIVISIONS OF THE PENNSYLVANIAN IN WASHINGTON AND ADJACENT COUNTIES

| Present Usage | | | Ohern, 1910[a] | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Northern Area | | | | Southern Area | |
| MISSOURI SUBSERIES | Ochelata Group | Strata tentatively referred to Weston shale of Kansas section | Sapulpa Group | Wann Formation | Higher rocks | | Sapulpa Group | Ramona Fm. — Avant ls. lens |
| | | Birch Creek ls. | | | Stanton ls. member | | | Ochelata member |
| | | Shale | | | | | | |
| | | Torpedo ss. | | | | | | |
| | | Wann formation[b] | | | Copan Member — Other ls. lentils | | | |
| | | Iola formation: Avant limestone, Muncie Cr. shale, Paola limestone | | | Copan Member — Avant ls. lentil | | | |
| | | Chanute shale | | | | | | |
| | Skiatook Group | Dewey limestone | | | Copan Member — Dewey ls. lentil | | | Dewey ls. lens |
| | | Nellie Bly fm. | | | | | | Skiatook Fm. — Ls. lens @ Lost City |
| | | Hogshooter ls. | | | Hogshooter ls. member | | | |
| | | Coffeyville fm.[c] | | Curl Fm.[d] | | | | "Lenapah" ls.[e] |
| | | Checkerboard ls. | | | | | Tulsa Group | Nowata Sh.[f] |
| | | Seminole fm. | | | | | | |
| DES MOINES SUBSERIES | | Lenapah ls. | | | Lenapah limestone | | | Oologah ls. |
| | | Nowata shale | Tulsa Group | | Nowata shale | | | |
| | | Oologah limestone | | | Oologah limestone | | | |

a. D. W. Ohern, "The Stratigraphy of the Older Pennsylvanian Rocks of Northeastern Oklahoma," *University of Oklahoma Research Bulletin 4* (1910).

b. Here revived, restricted, and redefined to apply to all strata between the top of the Iola formation, below, and the base of the Torpedo sandstone, above, or the base of the Birch Creek limestone in areas where the Torpedo sandstone was removed by pre-Birch Creek erosion.

c. Here restricted to the strata lying between the top of the Checkerboard limestone and the base of the Hogshooter limestone.

d. Equivalent exactly to the Coffeyville formation before the latter was restricted by elimination of the Checkerboard limestone and the Seminole formation.

e. Owing to an error in correlation, the "Lenapah" limestone of Ohern's southern area is not the Lenapah limestone of his northern area, but the Checkerboard limestone of present usage. See discussion by Ohern, p. 122, Vol. 2 of the *Bulletin*.

f. Owing to the same error mentioned under (e) above, the "Nowata shales" of Ohern's southern area embraced all strata between the top of the Oologah limestone and the base of the Checkerboard limestone including the Nowata shale, proper, the Eleventh Street limestone (now thought to be equivalent to the Lenapah), some overlying, upper Des Moines beds not represented in the northern area, and the Seminole formation.

at the top of the Drum (*Dewey*)[7] limestone (or where this limestone is absent, at the base of sandstone in the lowermost Chanute shale).

The Ochelata group was not changed and extends from the top of the Skiatook group to the top of the Missouri subseries.

SKIATOOK GROUP

*Seminole formation.*—The application of the term Seminole formation to certain beds in northeast Oklahoma was first proposed informally by Dott at the Tulsa Meeting of the Association, in 1936, and was formally proposed by Ware and Dott,[8] in 1937. Field studies by Newell justify the tentative correlation of the Checkerboard limestone with the DeNay limestone which lies immediately above the Seminole formation of the Stonewall quadrangle, and work by Dott indicates that the unconformity at the base of the Seminole formation in the southern area is coextensive with that at the base of the Missouri subseries in northeast Oklahoma and Missouri. These considerations led Moore, Newell, Dott, and Borden,[9] in 1937, to say:

> We are here extending application of the name Seminole northward to include the basal Missouri deposits in northeastern Oklahoma as far as the Kansas line, restricting definition of the Coffeyville to apply only to strata between the Checkerboard limestone, below, and the Dennis (Hogshooter) limestone, above.

*The Checkerboard limestone*, herein raised to formation rank, is shown on the Geologic Map of Oklahoma as extending from Okemah, Okfuskee County, to a point west of Nowata. In January, 1933, Ronald J. Cullen and Robert H. Dott, as a field research project of the Tulsa Stratigraphic Society, made reconnaissance studies in the vicinity of Nowata, and found a calcareous zone and limestone near the W. $\frac{1}{4}$ corner of Sec. 27, T. 26 N., R. 15 E., which they identified as Checkerboard because of its position above the upper Seminole sandstone. This zone was followed north to South Coffeyville, and limestone outcrops were seen in enough places to indicate that the Checkerboard is continuous to the Kansas-Oklahoma line. During the field season of 1938 John R. Davis, a graduate student of the University of Oklahoma, supervised by the writer, checked the mapping of the Checkerboard limestone from the vicinity of Tulsa to its northernmost extension, as shown on the Geologic Map of Oklahoma,

[7] Italics by the writer.

[8] John M. Ware and Robert H. Dott, in a contribution to "A New Pennsylvanian Cephalopod Fauna from Oklahoma," by A. K. Miller and John Britts Owen, *Journal of Paleontology*, Vol. 11, No. 5 (1937), pp. 403–04.

[9] *Op. cit.*, p. 41.

and added details to the mapping from that point to the Kansas-Oklahoma line, in the north edge of South Coffeyville.

Three criteria were most useful in tracing the outcrop. (1) The Checkerboard limestone, in this area, lies on a relatively thin sandstone of the upper part of the Seminole formation, the sandstone, in turn, being underlain by a very sandy shale. (2) The Checkerboard is overlain throughout by a black, fissile shale 3 to 30 feet thick, which contains, in the lower 2 feet, a persistent zone of small, rounded, black phosphatic nodules. This black shale and the overlying thick clay shale of the lower part of the Coffeyville formation yield a dark, sticky clay soil which is in sharp contrast to the sandy soil derived from the Seminole formation, below the Checkerboard limestone. (3) Phosphatic nodules, such as those in the black, fissile shale immediately above the Checkerboard limestone, are very resistant to weathering and, since they remain in the soil after all other constituents of the enclosing rock have become unrecognizable, they afford a reliable basis for tracing the horizon of the limestone between exposures.

It was found that in the northern part of the area the Checkerboard limestone is composed of at least three limestone members separated by gray, fossiliferous, calcareous shale. The following composite section may be taken as typical.

| | *Feet* |
|---|---|
| Coffeyville formation | |
| Black, fissile shale, with phosphatic nodules, at base | |
| Checkerboard limestone | |
| Limestone, gray, marly, fossiliferous, about | 1.0 |
| Shale, gray, calcareous, fossiliferous, about | 2.0 |
| Limestone, dense, dark bluish in color, nodular, fossiliferous, about | 1.0 |
| Shale, gray, calcareous, fossiliferous, about | 6.0 |
| Limestone, gray, sparingly fossiliferous, breaks into thin-edged plates and lenses in weathering | 1.0 |
| Seminole formation | |
| Thin sandstone at the top underlain by sandy shale | |

The lower limestone member of this section is prominent in most exposures. The upper members were seldom found in the northern part of the area and were not encountered south of Sec. 11, T. 25 N., R. 14 E. The black, fissile shale, with contained phosphatic nodules, in the base of the overlying Coffeyville formation, immediately overlies the highest member of the Checkerboard present in a given exposure. In view of this, it is possible that there was a slight amount of erosion between deposition of the Checkerboard limestone and that of the overlying Coffeyville formation.

*The Coffeyville formation* is here restricted to the strata lying between the top of the Checkerboard limestone and the base of the

Hogshooter limestone.[10] It comprises four shale zones and three sandstone zones, the boundaries of which are not well defined but are gradational in nature. The section here given may be taken as typical.

| | *Feet* |
|---|---|
| Hogshooter limestone | |
| Contains thin bed of limestone with phosphatic nodules at base | |
| Coffeyville formation | |
| Shale, gray, with coal seam 0.1 feet thick near base | 10.0 |
| Sandy shale and sandstone with coal seam 0.1 feet thick and 5 feet above base, probably Layton sand of subsurface | 35.0 |
| Shale | 25.0 |
| Sandstone | 15.0 |
| Shale | 45.0 |
| Sandstone | 20.0 |
| Shale, containing calcareous sandstone 10 feet below top which contains hematite and glauconite, lower 3 to 5 feet is black, fissile shale containing phosphatic nodules | 60.0 |
| Checkerboard limestone | |

*Hogshooter limestone.*—Tracing in the field demonstrated that the Hogshooter limestone of Ohern[11] is not correlative with the Drum limestone of Kansas, as the nomenclator thought, but is continuous with the Winterset limestone member of Jewett's[12,13,14] Dennis formation. The writer has checked the mapping of the Winterset limestone member from Coffeyville, Kansas, to the vicinity of Tulsa, Oklahoma. It varies in thickness from less than 5 to more than 25 feet, but at the base, throughout, is a distinctive bed, which is, as a rule, less than 1 foot thick, dark in color, packed with fragments of small crinoid stems and arms, and contains a band of phosphatic nodules.

West of Tulsa this bed rests on a massive limestone about 40 feet thick but of limited extent, known as the Lost City limestone. Locally, in Washington and Nowata Counties, the dark, crinoidal, phosphatic bed rests on black, fissile shale 3 to 10 feet thick, which in turn rests on a dense, fine-grained limestone 0.5 to 1 foot thick, correlated with the Stark shale and Canville limestone of Jewett's Dennis formation, of the Kansas section.

Dennis is an older name than Hogshooter and would ordinarily take precedence for that reason. However it seems advisable to retain

[10] Moore, Newell, Dott, and Borden, *op. cit.*

[11] D. W. Ohern, "The Stratigraphy of the Older Pennsylvanian Rocks of Northeastern Oklahoma," *University of Oklahoma Research Bull. 4* (1910), p. 28.

[12] John M. Jewett, "Brief Discussion of the Bronson Group in Kansas," *Kansas Geol. Soc. Guidebook*, Sixth Annual Field Conference (1932), p. 102.

[13] John M. Jewett and Norman D. Newell, "Geology of Wyandotte County, Kansas," *Kansas Geol. Survey Bull. 21*, Part 2 (1935), pp. 170–71.

[14] Norman D. Newell, "Geology of Johnson and Miami Counties, Kansas," *Kansas Geol. Survey Bull. 21*, Part 1 (1935), pp. 30–34.

the name Hogshooter, in Oklahoma, for the following reasons. (1) Dennis has been used in several senses in Kansas, and while it was recently redefined by Jewett, there seems to be a tendency to modify it still further,[15] and the heterogeneous nature of the lower part of the formation in Oklahoma would necessitate another redefinition. (2) The term Hogshooter already includes both the Winterset and Lost City members in the area west of Tulsa, and the Stark shale and Canville limestone have been mentioned in connection with the Hogshooter rather than the underlying Coffeyville formation, as in the following instances. Immediately following his description of the Hogshooter limestone, Bloesch says: "In sec. 16, T. 28 N., R. 15 E., black carbonaceous shale was observed underlying the limestone, also on the M. K. & T. R. R. southwest of Coffeyville."[16] The same author, referring to a personal communication by Dott, says: "A sample of such shale associated with the Hogshooter limestone collected behind the store at Hogshooter showed an oil content of two gallons to the ton."[17] Dott's original description of this sample in his field notebook, 1919, follows: "South side of road, west side of grade, behind store at Hogshooter, Oklahoma. In Hogshooter limestone." (3) Hogshooter is the oldest name used in Oklahoma for this formation and is firmly entrenched in literature and usage.

Hogshooter is therefore here retained as a formation name. In the north part of the area the section is as follows.

| | *Feet* |
|---|---|
| Nellie Bly formation | |
| Shale with sandstone beds in upper part | |
| Hogshooter limestone | |
| Winterset limestone member | 5 to 25 |
| (At base throughout is a dark, crinoidal bed containing phosphatic nodules) | |
| Stark shale member | 3 to 5 |
| (Black fissile shale, sometimes contains black sideritic concretions) | |
| Canville limestone member | 0.5 to 1 |
| (Dense fine-grained limestone with prominent vertical joints) | |
| Coffeyville formation | |

West of Tulsa the Hogshooter limestone consists of two members, the section being as follows.

| | *Feet* |
|---|---|
| Nellie Bly formation | |
| Shale with prominent sandstone zones | |
| Hogshooter limestone | |

[15] Raymond C. Moore, "Stratigraphic Classification of the Pennsylvanian Rocks of Kansas," *Kansas Geol. Survey Bull. 22* (1935), p. 97.

[16] Edward Bloesch, "Oil and Gas in Oklahoma," *Oklahoma Geol. Survey Bull. 40*, Vol. 3 (1930), p. 358.

[17] *Ibid.*, p. 363.

| | *Feet* |
|---|---|
| Winterset limestone member, about | 2 |
| (At base throughout is a dark, crinoidal bed containing phosphatic nodules) | |
| Lost City limestone member, about | 40 |
| (Gray, massive, fossiliferous limestone) | |
| Coffeyville formation | |

Over the greater part of the area only the Winterset limestone member is present.

*The Nellie Bly formation* remains as originally defined by Ohern[18]: "The Nellie Bly formation lies between the top of the Hogshooter limestone and the base of the Dewey." It "consists of alternating shales and hard gray to brown sandstones, the latter ranging in thickness from a few inches to several feet."

*The Dewey limestone* is equivalent to the Drum limestone of the Kansas section. Prior to the work of the writer, Bloesch, Borden, and others had noticed that the Dewey limestone does not exist north of the center of Sec. 13, T. 28 N., R. 14 E., and Newell had suggested that it was removed by post-Dewey-pre-Chanute erosion north of that point. The writer's field work has amply confirmed this suggestion. In places the erosion removed nearly if not quite all the underlying Nellie Bly formation.

OCHELATA GROUP

*The Chanute formation* extends into Oklahoma from Kansas and is limited below by the Dewey limestone, where the Dewey is present, and in other areas by the pre-Chanute erosion surface. Its upper limit is the base of the Iola formation. Along the Kansas-Oklahoma line, where the pre-Chanute erosion cut most deeply into the underlying strata, the section is as follows.

| | *Feet* |
|---|---|
| Iola formation | |
| Chanute formation | |
| Cottage Grove sandstone member, about | 40 |
| (Thinly and evenly bedded sandstone, fine-grained, micaceous, buff in color. A coal seam, 0.1 foot thick, or thinner, occurs at top of this sandstone from place to place) | |
| Shale member, about | 55 |
| (Dark clay shale containing Thayer coal zone as one or more thin seams in upper 15 feet. Upper part of this shale member, with its contained coal, overlaps eroded Dewey limestone in T. 28 N., R. 14 E.) | |
| Noxie[19] sandstone member, maximum about | 60 |
| (Sandstone, massive, coarse, cross-bedded, buff to reddish brown) | |
| Limestone conglomerate | 2 to 20 |

[18] D. W. Ohern, "Geology of the Nowata and Vinita Quadrangles," unpublished manuscript in the files of the Oklahoma Geological Survey.

[19] Moore, Newell, Dott, and Borden, *op. cit.*, p. 43.

(Varies from sandstone containing small fragments of limestone to conglomerate containing fragments of limestone as much as 2 inches in diameter in relatively pure limestone matrix)
Nellie Bly formation

The Cottage Grove sandstone and the underlying shale member have been traced to the south side of T. 23 N., R. 12 E. They vary greatly in thickness.

*The Iola formation* extends into Oklahoma from Kansas. In this area the section is as follows.

| | Feet |
|---|---|
| Wann formation | |
| Iola formation | |
| Avant limestone member. (Where thinnest it is commonly a mass of fragments of crinoid stems and arms) | 1 to 40 |
| Muncie Creek shale member. (Upper part ranges from clay shale to marly shale. Lower 1 to 3 feet consists of black fissile shale which contains phosphatic nodules) | 3 to 20 |
| Paola limestone member. (Granular, marly limestone. Across much of Washington and Nowata counties it is massive, well cemented sandstone as much as 3 feet thick in contrast with thin-bedded, rather soft underlying Cottage Grove sandstone. This massive sandstone phase is noticeably calcareous near top, the upper surface weathering pitted like that of limestone. From place to place it grades upward into true limestone less than 1 foot thick) | 0.5 to 3 |
| Chanute formation | |

The entire Iola formation is not more than 6 or 7 feet thick north and east of Caney River, but south and west of that stream it is thicker, owing to increasing thickness of the Muncie Creek shale and Avant limestone members.

In northeast Oklahoma phosphatic nodules are restricted to definite horizons which are widespread and far enough apart in the geologic section that they are not readily confused one with another. By following the band of phosphatic nodules weathering out of the Muncie Creek shale member it was possible to map the outcrop of the Iola formation with assurance and, in this way, exposures of the limestone members were found from place to place.

*Wann formation.*[20]—Between the top of the Iola formation below and the base of the Torpedo sandstone above is a unit to which the name Wann is herewith applied. The equivalent strata were first studied in Kansas where several units were recognized and named but none of these subdivisions can be recognized in southern Kansas or northern Oklahoma. This has caused uncertainty as to exact equivalents, and has led to the use of such hyphenated names as

[20] D. W. Ohern, "The Stratigraphy of the Older Pennsylvanian Rocks of Northeastern Oklahoma," *University of Oklahoma Research Bull. 4* (1915).

"Lane-Vilas," which are acceptable expedients in southern Kansas but are inadequate in Oklahoma. Since this unit is part of the Wann formation, as originally defined, and since the name has been little used and is appropriate, it is here revived, restricted and redefined to apply to all strata between the top of the Iola formation, below, and the base of the Torpedo sandstone, above, or the base of the Birch Creek limestone in areas where the Torpedo sandstone was removed by pre-Birch Creek erosion.

The Wann formation varies greatly in thickness and content. At the Kansas-Oklahoma line it is about 100 feet thick and consists essentially of shale. It maintains this thickness and character across Ts. 29 and 28 N., but south of T. 28 N., it increases in thickness to a maximum of nearly 300 feet in T. 25 N., decreasing again to about 230 feet in T. 23 N. It is characterized throughout by the preponderance of shale and by a calcareous to limestone zone, somewhat above the middle, carrying a distinctive assemblage of fossils which resembles, in some respects, the fauna of the Wewoka formation of the Des Moines subseries.[21] This calcareous zone extends southward from the Kansas-Oklahoma line to the south side of T. 23 N. and beyond. In T. 25 N. it contains limestone beds, some of which thicken and coalesce locally in Sec. 25, T. 24 N., R. 12 E., to form a continuous limestone section 40 feet thick. In Ts. 24 and 23 N., R. 12 E., in Osage County, the calcareous zone contains the "Shelley" limestone, the "fusulina-bearing gray" limestone, and the "red" limestone.[22] The Clem Creek sandstone[22] lies in the Wann formation above the calcareous zone. It reaches a maximum thickness of about 60 feet but thins northward and pinches out in the south part of T. 26 N., R. 12 E., Washington County.

*Torpedo sandstone*[23] *and overlying shale.*—The Torpedo sandstone is 0–60 feet thick. In Ts. 25 and 26 N. it consists, generally, of two divisions of massive, cliff-making sandstone separated by a shale parting. Elsewhere it contains prominent lenses of sandy shale and soft sandstone beds. In most places it is tree-bearing but in some areas it is grass-covered. It occurs continuously above the Wann formation from the Kansas-Oklahoma line, 0.1 mile east of the NW. corner of Sec. 13, T. 29 N., R. 13 E., to Sec. 15, T. 25 N., R. 12 E. At both its northern and its southern extremities it is cut off by an unconformity at the base of the Birch Creek limestone.

[21] George H. Girty, "Fauna of the Wewoka Formation of Oklahoma," *U. S. Geol. Survey Bull. 544* (1915).

[22] David White and others, "Structure and Oil and Gas Resources of the Osage Reservation, Oklahoma," *U. S. Geol. Survey Bull. 686* (1922), pp. 3, 238–39.

[23] *Ibid.*, p. 95.

The shale overlying the Torpedo sandstone is also cut off at its northern and southern extremities by the unconformity mentioned. As a rule, it crops out on grass-covered slopes where little can be seen of its character except its great variation in thickness, 0–90 feet, due to the pre-Birch Creek erosion which it suffered. It is best exposed in the north slope of the mound in the center of the east side of Sec. 15, T. 28 N., R. 13 E., where the lower 40 feet seems to be dark clay shale while the upper 30 feet seems to be lighter-colored calcareous shale, packed with crinoid stems, brachiopods, and bryozoa in the uppermost 10 feet.

*Birch Creek limestone.*—The limestone mapped by the writer as Birch Creek limestone has been previously mapped by various geologists as the Birch Creek limestone,[24] the Panther Creek limestone,[25] and the Stanton[26] or upper Stanton limestone. The principal cause for the confusion has been that each geologist worked in a limited area and thus lacked acquaintance with the problem as a whole. The Birch Creek limestone may be equivalent to the Little Kaw limestone member of the Stanton limestone of the Kansas section.[27]

Field study over the larger area mapped by the writer discloses that there was a period of considerable erosion immediately preceding deposition of the Birch Creek limestone, during which 100 feet or more of sediments were removed in some localities, and little or none in others. The Birch Creek limestone rests on the eroded top of three distinct units, the Wann formation, the Torpedo sandstone, and the shale above the Torpedo sandstone.

North of T. 24 N., R. 12 E., the Birch Creek limestone varies in thickness from 1 to 15 feet and, locally, includes considerable shale. Where it rests on Torpedo sandstone it is sandy and reddish brown in color. Where it rests on shale it is generally relatively pure to argillaceous and bluish white in color. Locally, the lower portion is sandy and reddish brown while the upper part is argillaceous, and bluish white in color. It contains crinoid stems throughout and locally brachiopods, bryozoa, and other fossils.

In T. 24 N., R. 11 E., and southward the Birch Creek limestone conforms closely to the description given by Bowen for the type locality in the bluffs on the north side of Birch Creek, near the east edge of the SE. $\frac{1}{4}$ of Sec. 25, T. 24 N., R. 10 E.

[24] *Ibid.*, p. 17.

[25] *Ibid.*, p. 397.

[26] *Ibid.*, p. 95.

[27] Raymond C. Moore, "Stratigraphic Classification of the Pennsylvanian Rocks of Kansas," *Kansas Geol. Survey Bull. 22* (1935), p. 136.

It is a hard light-gray crystalline, somewhat dolomitic limestone and is sparingly fossiliferous. It contains a considerable percentage of iron, which gives it an unusually high specific gravity and produces a deep rusty brown color on the weathered surface. Laterally it grades into limey sandstone.[28]

While not differentiated on the accompanying map, the Okesa sandstone and underlying shale deserve special mention in connection with the Birch Creek limestone and Torpedo sandstone. For purposes of this discussion the Okesa sandstone and underlying shale are considered as one unit under the term Okesa sandstone, but formal redefinition of Okesa will not be attempted until further field studies have been made. The Okesa, thus considered, lies immediately above the Birch Creek limestone. It is composed, at the base, of sandy shale and sandstone, in some localities, and of clay shale to sandy shale in others, and culminates at the top in the Okesa sandstone of Clark.[29] The unit is wholly sandstone in Ts. 24 and 25 N., Rs. 11 and 12 E., where the underlying Birch Creek limestone overlaps the eroded edge of the Torpedo sandstone. The Birch Creek limestone is itself sandy and inconspicuous in this locality, but it is not difficult to distinguish the Okesa from the Torpedo sandstone. The Okesa sandstone is even and thin-bedded and contains abundant fossils in the form of casts and molds, while the Torpedo is massive and nearly devoid of fossils.

The extremely variable nature of the Birch Creek limestone and its various associations with sandstone and shale, both above and below, contributed considerable confusion to the task of correlating its various exposures. For instance, it appeared to Hopkins, who did not recognize the presence of an unconformity, that the Okesa and Torpedo sandstones merged into one series, by thickening of the Okesa of Clark at the expense of its underlying shale, in Ts. 24 and 25 N., Rs. 11 and 12 E. He thought the Birch Creek limestone lay "at the base or at some places 12 to 15 feet above the base of this series of sandstones"[30] in T. 24 N., R. 11 E., and therefore at or near the base of the Torpedo sandstone. In this township the Birch Creek locally rests on pre-Birch Creek remnants of Torpedo sandstone and therefore is at the base of the Okesa, as elsewhere, rather than at the base of the combined Okesa-Torpedo unit. Hopkins saw limestone in the north part of T. 25 N., R. 12 E.[31] (later named the Panther Creek) but since it was clearly above the Torpedo sandstone, which

[28] David White and others, "Structure and Oil and Gas Resources of the Osage Reservation, Oklahoma," *U. S. Geol. Survey Bull. 686* (1922), p. 17.

[29] *Ibid.*, p. 95.

[30] *Ibid.*, p. 239.

[31] *Ibid.*, p. 77.

is at that point 15–20 feet thick, he believed that this limestone was 15–20 feet above the horizon of the Birch Creek. Field work and the stratigraphic considerations set forth above convince the writer that the Birch Creek and Panther Creek limestones are directly equivalent. Since Birch Creek has priority it is retained as the proper name.

*Strata above the Birch Creek limestone* in the northwestern part of Washington County comprise about 300 feet of section and include the Okesa sandstone, Hulah sandstone, Cheshewalla sandstone, and associated shales. No attempt will be made to consider them separately, since they are unimportant in Washington County. With the possible exception of the Cheshewalla sandstone all are in the Missouri subseries of the Pennsylvanian series and referable to the Weston shale of the Kansas section. The Cheshewalla occurs as an outlier in the extreme northwest corner of the county and may lie above the unconformity which marks the top of the Missouri. The Okesa sandstone, as previously mentioned, carries fossils locally in the form of casts and molds, and limestone beds[32] are not unknown. This unit becomes more shaly and calcareous northward and it is the writer's opinion that the limestone beds present in the hills in Secs. 16 and 17, T. 29 N., R. 13 E., are to be referred to the Okesa sandstone, probably being equivalent to the Stanton (?) limestone of Goldman.[33]

[32] *Ibid.*, p. 95.

[33] *Ibid.*, pp. 366–67.

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# GEOLOGICAL NOTES

## RECENT SHORELINE PROCESS, BRAZORIA COUNTY, TEXAS[1]

WILLIAM H. CURRY[2]
San Antonio, Texas

In the course of a general discussion on the subject of sedimentation, Clay McGaughy of the Kargl Aërial Surveys Company, Ltd., brought to our attention a series of aërial photographs. Pictures taken by that concern on December 9, 1938, along the shoreline of the Gulf

FIG. 1.—Shoreline northeast of mouth of Brazos River, Brazoria County, Texas, December 9, 1938, showing normal sedimentation and suggesting normal current action. Courtesy, Kargl Aërial Surveys Company, Ltd., San Antonio, Texas.

of Mexico in the vicinity of the Brazos River mouth, Brazoria County, Texas, recorded only normal current action. In a reflight of the same area 42 days later, on January 20, 1939, an exceptional cloud was seen in the water offshore where previously there had been none. The exact

[1] Manuscript received, February 7, 1940.

[2] Wellington Oil Company of Delaware.

location of the aërial photographs is 3 miles northeast of the mouth of the Brazos River. It is assumed that some condition has changed the sedimentation in the Gulf near the mouth of the river and along-shore currents have caused it to drift northeastward. Any change in the normal sedimentation at the river mouth would undoubtedly be related to changes in the weather between the dates of the photographs.

FIG. 2.—Shoreline northeast of mouth of Brazos River, Brazoria County, Texas, January 20, 1939, showing sedimentary cloud offshore which was not present when previous photograph was taken. Courtesy, Kargl Aërial Surveys Company, Ltd., San Antonio, Texas.

In checking reports of the United States Weather Bureau, we find that on January 12, eight days prior to the second photograph, there was a heavy rainfall of 3.10 inches at Freeport which is the nearest recording station to the locality in question. Charts published in the *Monthly Weather Review* for January, 1939,[3] show that a cyclone originated on the Mexican Plateau, January 11, and moved northeastward in such a manner that on January 12 the feature was off the Texas Coast at approximately the location of the photographs. The farther northeastward course of this storm took it across Louisiana and up the Mississippi Valley. A second chart shows by cross-hatching

[3] *Monthly Weather Review* (January, 1939), United States Department of Agriculture, Weather Bureau, Washington, D. C.

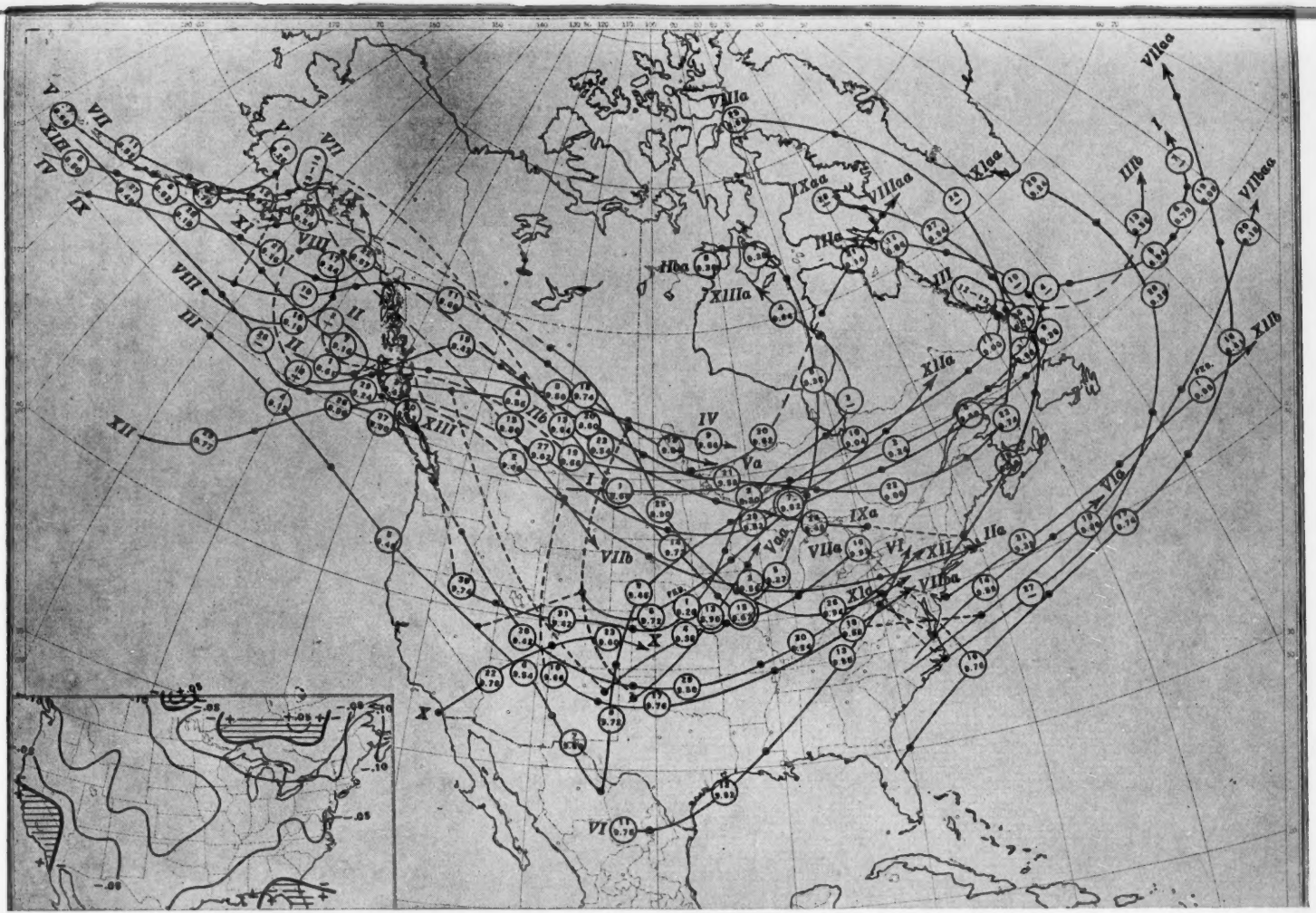

FIG. 3.—Chart III, Tracks of Cyclones, January, 1939, *Monthly Weather Review*, Vol. 67, No. 1, showing storm originating in northern Mexico on January 11 and moving northeastward, where it appeared off Brazoria County, January 12. Courtesy of United States Weather Bureau, Department of Agriculture.
Circle indicates position of cyclone at 7:30 A.M. (75th meridian time), with barometric reading. Dot indicates position of cyclone at 7:30 P.M. (75th meridian time).

FIG. 4.—Chart V, Total Precipitation, Inches, January, 1939, *Monthly Weather Review*, Vol. 67, No. 1, showing Brazoria County as being in zone of heavy rainfall. Heaviest precipitation occurs along belt approximating the track of January 12 cyclonic storm. Courtesy of United States Weather Bureau, Department of Agriculture.

the areas of heavy rainfall for the month of January. It will be noticed that this rainfall map shows a northeast-southwest elongation which corresponds with the track of the cyclonic storm and that the coast line of Brazoria County was in a zone of heavy rainfall, varying from 2 to 4 inches.

Therefore, it is concluded that rainfall attending the storm of January 12 caused greater alluviation in the Brazos River mouth and that the northeastward drift along the coast was effected in part by currents caused by the northeastward movement of the cyclone. Moreover, the storm may have disturbed the recent sediments off the River mouth, causing them to be redistributed along with new material. The direction of drift by the sedimentary cloud is also indicated by the shape of its eastern end which suggests the blunt nose of a northeastward-moving body.

Geologically, this phenomenon is of interest since it definitely records in dates an act of sedimentation along the Gulf Coast. This significance was first noticed by Frank A. Melton, specialist in the geological interpretation of aërial photographs at the University of Oklahoma. It was originally thought that the newly formed sedimentary feature might be a sand bar in the act of formation. The light color does suggest sand, photographically. However, since the feature extends off the photograph, its width is 2.5 miles or more, which is believed to be too broad for a sand body. It is suggested that the sedimentary material might be fine silt suspended in the water which would permit its being carried along shore and spread over a larger area. However, whether or not the material is sand, the geologic principles of sedimentation are the same. To our knowledge, this is the first time that such a shoreline process has been photographed and dated.

FIG. 4.—Chart V, Total Precipitation, Inches, January, 1939. *Monthly Weather Review*, Vol. 67, No. 1, showing Brazoria County as being in zone of heavy rainfall. Heaviest precipitation occurs along belt approximating the track of January 12 cyclonic storm. Courtesy of United States Weather Bureau, Department of Agriculture.

## DEEPEST WELL IN MID-CONTINENT REGION, WASHITA COUNTY, OKLAHOMA[1]

W. BAXTER BOYD[2]
Ponca City, Oklahoma

On January 6, 1940, the Continental Oil Company plugged and abandoned its Proctor No. 1, in the center of the NW. ¼, Sec. 28, T. 10 N., R. 20 W., Washita County, Oklahoma, at a depth of 14,582 feet in the Bend (?) group (lower Pennsylvanian). It is the second

[1] Manuscript received, February 11, 1940.

[2] Continental Oil Company.

deepest well in the world and has established a new record for depth in the Mid-Continent area. Proctor No. 1 is located on an anticline, mapped by seismic surveying, the axis of which is parallel with the Wichita Mountains.

From a geological viewpoint, this well has added important information about the thickness and the lithologic character of the Pennsylvanian series in the Anadarko basin of western Oklahoma. In this locality, the thickness of the Pennsylvanian series exceeded all previous estimates; approximately 9,450 feet was penetrated without reaching the base. This amount is remarkable, in view of the fact that pre-Cambrian granite crops out only 23 miles south. The lithologic character of the Pennsylvanian series is similar to the Texas Panhandle section instead of the Oklahoma section, as it is developed in the Cement pool, 45 miles southeast. The section at Cement is predominantly sandstone and shale, whereas the section in the Proctor well is predominantly limestone with arkose. The accompanying table shows the subdivisions and general description of the formations which were encountered.

The Permian series was encountered approximately as it was anticipated, with few exceptions as here enumerated.

1. The Duncan and Garber sandstones have graded into red shales.

2. There are no criteria for identifying the top of the Clear Fork group; consequently, the Duncan and Clear Fork are grouped together.

3. The zone in the lower part of the Wichita group, which produces gas in the Sayre field, 15 miles west by southwest, is poorly developed and had no showings of oil or gas.

The group subdivisions from the Cisco to the Bend were based on general lithologic criteria, aided by the identification of a few fossils. Incidentally, the formations contained very few fossils. The most impressive feature of the Cisco, Canyon, and upper Strawn groups is the more or less continuous occurrence of arkose throughout. Even the lower part of the Strawn has arkose in places, the last appearance being from 13,430 to 13,445 feet. This demonstrates that the Wichita Mountains were repeatedly furnishing a part of the sediments throughout Pennsylvanian time. Cores taken at intervals showed dips, in beds above 13,300 feet, varying from 2° to 7°, and demonstrated that this thick Pennsylvanian section was not due to steep dips. Below this depth, the only core taken showed dips as steep as 26° in a cross-bedded shale. At no place did the hole vary more than 2.5° from vertical.

| Series | Group or Formation | Depth in Feet From | To | Thickness in Feet | General Description Figures in Feet |
|---|---|---|---|---|---|
| PERMIAN | Quartermaster group | 0 | 305 | 305 | No samples, 0–285; red shale, 285–305 |
| | Whitehorse group | 305 | 1,050 | 745 | Top, 250; Cloud Chief gypsums, red shales, and some red sandstones. Bottom, 495; fine red sand with gypsum in upper part |
| | Dog Creek shale | 1,050 | 1,308 | 285 | Red shale |
| | Blaine formation | 1,308 | 1,556 | 248 | Interbedded gypsum and red shale, some dolomitic limestone in middle part |
| | Flower Pot shale | 1,556 | 1,650 | 94 | Red and grayish green shales |
| | Duncan-Clear Fork group | 1,650 | 3,977 | 2,327 | Red shale with thin beds of grayish green shale; thin beds of gypsum and dolomitic limestone in bottom 500 |
| | Wichita group | 3,977 | 4,460 | 483 | Top, 228; anhydrite. Middle, 155; interbedded anhydrite, greenish gray shales, and dolomitic limestones. Bottom, 100; dolomitic limestone, some interbedded anhydrite |
| PENNSYLVANIAN | Cisco group | 4,460 | 7,290± | 2,830± | Top, 1,970; maroon shale with varying amounts of arkose. Bottom, 860; interbedded limestone, arkose and maroon shale |
| | Canyon group | 7,290± | 10,380± | 3,090± | Limestone with considerable arkose present, some thin shale beds |
| | Strawn group | 10,380± | 14,025± | 3,645± | Top, 2,150; predominantly limestone with some arkose and limestone conglomerate, some dark gray calcareous shales, several shows of gas in more sandy phases. Bottom, 1,495; interbedded dark gray shale and limestone, some conglomerate traces of arkose, few shows of gas |
| | Bend group? | 14,025± | 14,582 | 557+ | Dark gray to black shale with thin beds of dolomitic limestone |

Several showings of gas were noted in the Strawn group between 10,700 and 13,400 feet in thin sandy limestones and conglomerates. Gas showed strongly in the mud and nearly caused the mud to be blown from the hole several times. Mechanical difficulties prevented a thorough test of all the gas-bearing beds, but judged from its action in the mud and from one test through collapsed casing, the gas was low in volume with high pressure. One of its peculiar manifestations was its action on the cable during the Schlumberger electrical survey. When the cable was withdrawn from the hole it developed a bad case of the "bends"; gas had so impregnated the cable that its expansion ruined several thousand feet of the insulation. An examination of the samples indicated that the porosity of the gas-bearing beds was low. This was confirmed by the Schlumberger electrical survey. Yet, these beds were apparently creviced. While gas was showing in the mud, a delicate balance had to be maintained in the density of the mud. If the density became more than 10.8 or 10.9 pounds per gallon, returns would be lost; if the density became lower than 10.6 pounds per gallon, the gas caused trouble. Associated with the gas-bearing beds throughout the Strawn group were carbonaceous or lignitic shales, which probably served as source beds for the gas.

A Schlumberger temperature survey taken at 13,400 feet showed a maximum temperature of 206°F.

Deeper drilling was hindered by mechanical difficulties which developed from caving shale in the Bend (?) group.

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## DORCHEAT POOL, COLUMBIA COUNTY, DEEPEST IN ARKANSAS[1]

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Shreveport, Louisiana

The Dorcheat pool of Columbia County, Arkansas, was discovered by The Atlantic Refining Company at its Pine Woods Lumber Company No. 1 in Sec. 16, T. 18 S., R. 22 W., on August 29, 1939, and became the deepest producing field in the state. With total depth of 9,002 feet and 5½-inch casing perforated from 8,861 to 8,875 feet with 56 shots, the well was washed into production, flowing at the rate of 13 barrels of 43.4° oil per hour through a 12/64-inch tubing choke with tubing pressure of 1,250 pounds and casing pressure of 2,250 pounds. The gas-oil ratio was originally computed at 1,000:1, but has gradu-

[1] Manuscript received, February 11, 1940.

[2] The Atlantic Refining Company.

ally increased until at present it is 7,000:1. The gravity has likewise increased from 43.4° to 56.9° which places present production in the classification of a straw-colored distillate. Several days after completion the well began to produce a small quantity of salt water which rose to 5 per cent and has remained constant ever since. This was at first thought to be due to a faulty cement job, but now is generally considered to be bottom-hole water, since later tests have demonstrated that the bottom of the perforations is very close to the oil-water contact.

Geologists had been aware of the presence of a low flat structural nose or terrace in the Upper Cretaceous formations for a number of years, but it remained for the reflection seismograph to define it in the deeper beds, inasmuch as it is known that all structures in southern Arkansas shift their position with depth. Several shallow dry holes had been drilled in the area to test the Upper Cretaceous formations, but the discovery well was the first to test the Lower Cretaceous and older sediments. Important tops in the Pine Woods No. 1 were logged as follows, with elevation of 220 feet.

| *Formation* | *Depth in Feet* | *Formation* | *Depth in Feet* |
|---|---|---|---|
| Nacatoch | 1,842 | James limestone | 4,740 |
| Saratoga | 2,190 | "Travis Peak" | 5,184 |
| (Base, Annona | 2,528) | Cotton Valley | 6,501? |
| Paluxy | 3,376? | Buckner formation | 8,754 |
| Massive anhydrite | 4,050 | Smackover limestone | 8,798 |
| (Base, massive anhydrite | 4,220) | | |

Oil is being produced from the Reynolds oölitic member of the Smackover limestone, which here is much less porous and permeable than in the Magnolia field of the same county. The porosities range from 2 to 20 per cent with an average of about 12 per cent, while the permeabilities range from 0 to 634 millidarcys with most of them less than 100. Wells drilled to date have a total porous section of about 75 feet with about one-third of this section too tight to produce. The gas-oil contact has been fairly well established at about minus 8,630 feet and the top of the water at minus 8,655 feet, giving an oil zone of approximately 25 feet. Present indications are that wells will have gas-oil ratios varying from 5,000 to 10,000:1 shortly after being brought into production, even when perforated in the bottom part of the oil zone.

Three producing wells had been completed at the beginning of 1940 with two more due for completion during the month of January. Another test, 3.5 miles northwest of the discovery is drilling below 8,000 feet.

The spacing for the field has been fixed at 40 acres by the Arkansas Oil and Gas Commission and the January allowable at 300 barrels of oil per day from each well. Total production for the field to the first of 1940 was 39,130 barrels, all of which with the exception of 3,147 barrels was produced by the discovery well. The leases are divided among many operators, but it is anticipated that future drilling will proceed in a conservative and orderly manner due to the high cost of drilling 9,000-foot holes and the comparatively thin oil zone.

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## MODELS OF KETTLEMAN HILLS NORTH DOME, CALIFORNIA[1]

JOHN H. MAXSON[2]
Pasadena, California

The Kettleman North Dome Association has presented to the division of the geological sciences of the California Institute of Technology as an indefinite loan a series of three-dimensional models of Kettleman Hills North Dome. They have been on display at the Golden Gate Exposition in San Francisco during 1939. As is generally known, the North Dome of Kettleman Hills is one of the principal oil fields of the state. It is located on the west side of the San Joaquin Valley and is about 16 miles long and about 3 miles wide.

The models were constructed by Martin Van Couvering, consulting petroleum engineer and geologist of Los Angeles, for use in one of the most important lawsuits ever tried in California, in which he testified for the defendant, Kettleman North Dome Association. The trial began on November 4, 1936, and ended on July 20, 1938. The Court's opinion was rendered in a 328-page volume in January, 1939. It is one of the most exhaustive and scientific opinions ever handed down by a California court.

The lawsuit was brought against the Kettleman North Dome Association by certain of its member companies who argued that the board of directors had exceeded its powers in declaring some of the land held by the Association as being non-productive and thereby reducing the participation in the Association on the part of those members whose land had been so declared non-productive.

The unit agreement, under which the Association operates, provides that the participation in the affairs of the Association shall be directly related to the acreage that has not been declared non-productive by the board of directors. The unit agreement requires that

[1] Manuscript received, February 17, 1940.

[2] Assistant professor of geology, California Institute of Geology.

the board must make such a determination annually and it has done so at least once a year, except at the end of the first year. At the end of 10 years from January 31, 1931, no more changes of status are permitted, and the participation of the different members will be fixed from that time on. This period of 10 years was provided for the purpose of allowing the limits of the field to be explored because, at the beginning, they were poorly defined on account of the small number of wells that had been drilled at that time.

The largest model is about 16 feet long and 6 feet high, and shows the development of the oil field by 5/16-inch steel rods, representing the wells, suspended from an upper platform. These rods show the stratigraphy by bands of color and the depths of the wells by the lengths of the rods. The entire model is on a scale of 500 feet to the inch in all three dimensions. The rods are removable so that the development of the field at different stages may be shown.

There are three other models on a scale of 1,000 feet to the inch, representing, respectively, surface topography, surface structure and subsurface structure. The topographic model shows the principal roads, locations of the derricks, and the geological contacts. This one can be removed and the model of the surface structure substituted in a cabinet which was built in such a manner as to place them in the correct vertical relation to the one of the subsurface structure. Whichever of the upper models occupies that part of the cabinet can be tilted back to show the lower one. The model of the surface structure is a three-dimensional representation of a map, made by W. P. Woodring and Ralph Stewart of the United States Geological Survey, which shows contours on an oölite bed at the base of the San Joaquin formation.

The model of the subsurface structure has contours on its upper surface defining the top of the productive Temblor formation. It is cut in such a way that, by removing various segments, the subsurface structure and stratigraphy are shown, in cross-sectional aspect, at various points across and along the field.

The models are now on exhibit in the museum of the division of the geological sciences, California Institute of Technology. They are proving instructive to students in petroleum geology at the California Institute and to geological students of neighboring institutions. Geologists visiting in southern California are cordially invited to examine the models in the museum, located at 1201 East California Street, Pasadena, California.

# PALOMA OIL FIELD, KERN COUNTY, CALIFORNIA[1]

ROBERT W. CLARK[2]
Los Angeles, California

The discovery of the Paloma oil field is an unquestioned achievement of reflection-seismograph methods. The field lies on the old abandoned bed of Buena Vista Lake with no outcrops near and no

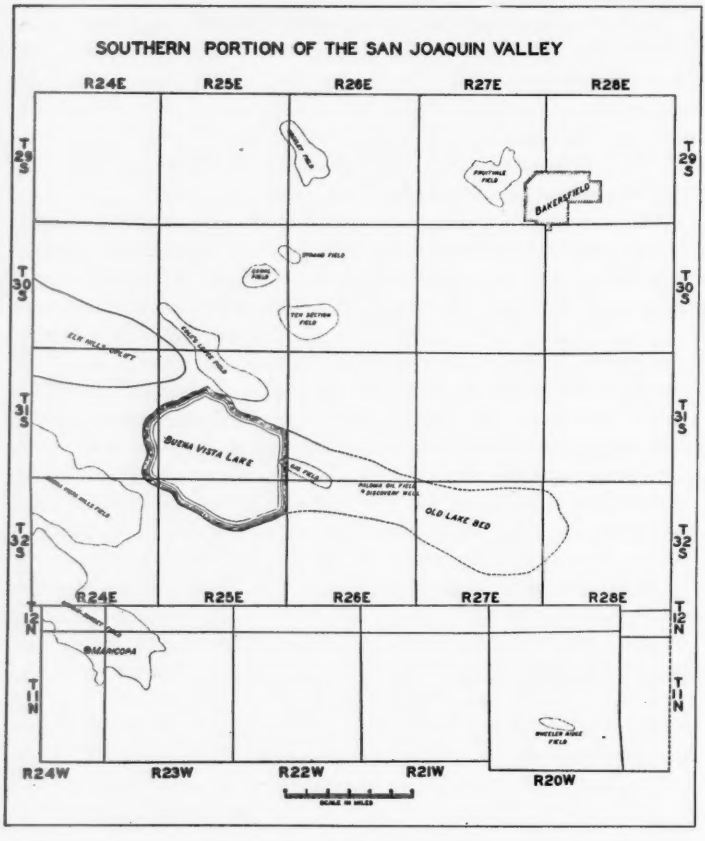


FIG. 1

[1] Manuscript received, February 29, 1940. Published by permission of the Western Gulf Oil Company.

[2] Chief geologist, Western Gulf Oil Company.

topographic relief that would indicate structure. In fact, most of the relief is due to the banks of irrigation ditches and does not exceed 5 feet. However, the seismograph survey shows a buried anticline with its axis trending approximately N. 60° W. and plunging southeast. The flanks show dips up to 15° and the total uplift is several hundred feet. It appears that the axis of the Elk Hills uplift plunges southeast under the valley floor and that the Paloma structure is a nose on this anticline. The Coles Levee field lies on the north flank of the uplift.

The discovery well was completed, August 31, 1939, by the Western Gulf Oil Company and The Texas Company, at a depth of 10,178 feet. On a drill-stem test it produced in 2 hours at the rate of 1,100 barrels of 51° Bé. oil per day and 10 million cubic feet of gas. The interval of sand open for this test was 170 feet. The location of the test is 330 feet north and 330 feet east of the center of Sec. 3, T. 32 S., R. 26 E. It is about 8 miles south of the Ten Section field and 7 miles southeast of the Coles Levee field and lies on the featureless plain of the San Joaquin Valley floor.

The columnar section here is similar to that at Ten Section, except for thickening toward the south, and may be represented as shown in the following tabulation.

| *Series* | *Formation* | *Thickness in Feet* | *Character* |
|---|---|---|---|
| Quaternary | | ? | Lake and fan deposits |
| Pleistocene | Tulare | 4,000± | Sands and siltstones |
| Pliocene | San Joaquin clay | 1,455 | Claystones and siltstones, some sandstone beds |
| | Etchegoin and Jacalitos | 3,300± | Sandstones and siltstones and hard shales |
| | Reef Ridge | 400± | Shales and siltstones |
| Miocene | McLure | 800+ | Brown siltstones and shales, cherty at base |
| | Santa Margarita (Stevens) | 1,100+ | Sands and hard siltstones |

The sandstone beds in the San Joaquin clay vary up to 15 feet in thickness and are productive of gas in the old Buena Vista Lake gas field about 2 miles northwest of the Paloma discovery well. They have not been tested in the new Paloma development but are cased off behind the water string of pipe. The productive formation at Paloma is the Stevens sand. The full thickness of this member has not been tested yet, but judged from near-by fields and dry holes there should be more than 1,100 feet of section consisting of approximately 50 per cent sand and 50 per cent siltstone or shale in alternating beds. What part of this will produce petroleum is still undetermined since the water level has not yet been found. The sandstones have a fairly uni-

form porosity of 18–20 per cent but the permeability varies from zero in the hard, tightly cemented sandstone shells to more than 400 millidarcys in the softer sands. The average permeability would be about 75 millidarcys.

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## PRE-CAMBRIAN AND CAMBRIAN RELATIONS IN EAST-CENTRAL MINNESOTA[1]

A. J. CROWLEY[2] AND G. A. THIEL[3]
Wichita, Kansas, and Minneapolis, Minnesota

One of the difficult stratigraphic problems of the Upper Mississippi Valley region is the determination, from drill cuttings, of the position of the contact between the basal St. Croixian and the top of the upper Keweenawan sandstones. The uppermost member of the Keweenawan sediments in Minnesota is the Hinckley sandstone. This formation is lithologically very similar to the lower part of the Mt. Simon member of the Dresbach formation which represents the basal St. Croixian of Upper Cambrian age.

TABLE I

UPPER CAMBRIAN AND UPPER KEWEENAWAN CLASSIFICATION OF EAST-CENTRAL MINNESOTA*

Upper Cambrian
- St. Croixian series
  - Jordan formation
    - Van Oser member
    - Norwalk member
  - St. Lawrence formation
    - Lodi member
    - Nicollet Creek member
  - Franconia formation
    - Bad Axe member
    - Hudson member
    - Taylors Falls member
    - Ironton member
  - Dresbach formation
    - Galesville member
    - Eau Claire member
    - Mt. Simon member

Upper Keweenawan
- Hinckley formation
- Red Clastic series

* C. R. Stauffer, G. M. Schwartz, and G. A. Thiel, "St. Croixian Classification of Minnesota," *Bull. Geol. Soc. America*, Vol. 15, (1939), pp. 1227–44.

The similarity between these two formations has led to various structural and paleophysiographic interpretations and was respon-

[1] Manuscript received, March 7, 1940.

[2] University of Wichita.

[3] University of Minnesota.

sible also for the conclusions reached by Atwater and Clement,[4] who postulate that the Hinckley sandstone does not occur as far south as the Twin Cities artesian basin.

It is difficult likewise to draw a sharp boundary between the base of the Hinckley sandstone and the top of the Red Clastic series (Table I). However, a detailed petrographic study of numerous drill cuttings and outcrop samples, from widely separated areas, has shown a marked difference in the quantity and character of the feldspar in the three formations. These differences, together with those of the heavy-mineral assemblages, are so uniform that they may be used for correlative purposes and for delimiting the Hinckley as a sedimentary unit.

## LABORATORY PROCEDURE

In view of the fact that quartz has a higher specific gravity than both orthoclase and albite, the feldspars in an arkosic sandstone may be separated from the quartz and the heavy accessory minerals by means of the centrifuge. Bromoform was diluted with alcohol until the resulting solution failed to support a piece of clear vein quartz, but floated a large cleavage fragment of pure albite.

Duplicate samples were centrifuged with this heavy liquid at 3,000 revolutions per minute for 5 minutes. At the end of this period the centrifuge tubes were removed and a small glass ball cemented to one end of a glass rod, was thrust into each tube to seal the quartz and heavy minerals in the tapered bottom ends of the tubes. In this way the feldspar could be floated from the top of the tubes without becoming contaminated with the heavier minerals.

The outcrop samples used for this study were collected for the "Pre-Cambrian Accessory Minerals" Project of the Geological Society of America, financed by the Penrose Bequest. The opportunity to use these samples for further petrographic investigation is hereby gratefully acknowledged.

## LABORATORY OBSERVATIONS

The percentage distribution of feldspar in the Red Clastic series, in the Hinckley sandstone and in the Mt. Simon sandstone is shown in Tables II–IV. It is at once evident that the percentage is uniformly high in the Red Clastic sediments and uniformly very low in the Hinckley sandstone, with the Mt. Simon yielding two to four times as much as the Hinckley but far less than the Red Clastic beds.

After having made the above observations on samples from known

[4] G. I. Atwater and G. M. Clement, "Pre-Cambrian and Cambrian Relations in the Upper Mississippi Valley," *Bull. Geol. Soc. America*, Vol. 46, pp. 1659–86.

TABLE II

PERCENTAGE BY WEIGHT OF FELDSPAR IN OUTCROP SAMPLES AND DRILL CUTTINGS OF RED CLASTIC SERIES

| *Sample No.* | *Location* | *Percentage Feldspar* |
|---|---|---|
| 1 | Mission Creek Quarry wall (near Fond du Lac) | 27.6 |
| 2 | 40 feet below No. 1 | 31.4 |
| 3 | Chambers Grove Quarry wall | 54.3 |
| 4 | 30 feet below No. 3 | 36.8 |
| 5 | 10 feet below No. 4 | 67.1 |
| 6 | Cliff along St. Louis River | 41.6 |
| 7 | Cliff along St. Louis River | 24.3 |
| 8 | Railroad cut near Chambers Grove | 68.3 |
| 9 | 10 feet below No. 8 | 27.2 |
| 10 | Deep well, Rosemont, Minnesota, 1,040 feet below surface | 45.1 |
| 11 | 50 feet below No. 10 | 72.3 |
| 12 | Deep well, Mankato, Minnesota, 1,060 feet below surface | 21.3 |
| 13 | 100 feet below No. 12 | 53.7 |
| 14 | Deep well, Lake City, Minnesota, 700 feet below surface | 47.4 |

TABLE III

PERCENTAGE BY WEIGHT OF FELDSPAR IN OUTCROP SAMPLES AND WELL CUTTINGS OF HINCKLEY SANDSTONE

| *Sample No.* | *Location* | *Percentage Feldspar* |
|---|---|---|
| 1 | Type section at Hinckley | 0.12 |
| 2 | Composite sample, Quarry wall at Sandstone, Minnesota | 0.29 |
| 3 | Road cut west of Askov | 0.26 |
| 4 | Outcrop along Willow River | 0.26 |
| 5 | Outcrop southeast of Rutledge, Minnesota | 0.31 |
| 6 | Outcrop along Net River | 0.18 |
| 7 | Drill cuttings from near top, Federal Prison well at Sandstone | 0.30 |
| 8 | 50 feet below No. 7 | 0.24 |
| 9 | 50 feet below No. 8 | 0.21 |
| 10 | 50 feet below No. 9 | 0.28 |
| 11 | 50 feet below No. 10 | 0.27 |
| 12 | 50 feet below No. 11 | 0.25 |
| 13 | 50 feet below No. 12 | 0.30 |
| 14 | 50 feet below No. 13 | 0.23 |
| 15 | Bottom of well, 465 feet below surface | 0.28 |

TABLE IV

PERCENTAGE BY WEIGHT OF FELDSPAR IN MT. SIMON SANDSTONE AT AND NEAR ITS TYPE LOCATION AT EAU CLAIRE, WISCONSIN

| *Sample No.* | *Location* | *Percentage Feldspar* |
|---|---|---|
| MS 1 | Type section 0–10 feet below top | 2.06 |
| MS 2 | Type section 10–20 feet below top | 2.18 |
| MS 3 | Type section 20–30 feet below top | 2.10 |
| MS 4 | Type section 30–40 feet below top | 2.27 |
| MS 5 | Type section 40–50 feet below top | 3.01 |
| MS 12 | Type section 110–120 feet below top | 4.03 |
| MS 7 | Basal conglomerate, Chippewa Falls | 2.89 |
| MS 8 | 1–10 feet above No. MS 7 | 3.88 |
| MS 9 | 10–20 feet above No. MS 8 | 3.07 |
| MS 10 | 20–30 feet above No. MS 9 | 3.18 |
| MS 11 | 30–45 feet above No. MS 10 | 4.20 |

stratigraphic units, the same laboratory procedure was adapted for well cuttings in an attempt to establish the stratigraphic limits of the Hinckley sandstone in the region to the south of its area of outcrop. Tables V–VII represent the results of such an investigation.

TABLE V

PERCENTAGE DISTRIBUTION OF FELDSPAR IN CUTTINGS FROM LOWER 220 FEET OF WELL AT SOUTH ST. PAUL (SURFACE ELEVATION, 700 FEET)

| | *Depth of Sample in Feet* | *Percentage Feldspar* |
|---|---|---|
| Mt. Simon | 675–680 | 2.81 |
| | 685–690 | 3.70 |
| | 700–705 | 6.11 |
| | 705–710 | 5.90 |
| | 715–720 | 3.88 |
| | 725–730 | 2.18 |
| | 730–735 | 2.07 |
| | 735–740 | 2.15 |
| | 740–745 | 2.06 |
| | 745–750 | 2.10 |
| | 750–755 | 1.61 |
| | 760–765 | 1.90 |
| Hinckley | 770–775 | 0.24 |
| | 780–785 | 0.43 |
| | 785–790 | 0.11 |
| | 805–810 | 0.25 |
| | 825–830 | 0.30 |
| | 855–860 | 0.28 |
| | 865–870 | 0.27 |
| | 890–895 | 0.30 |

TABLE VI

PERCENTAGE DISTRIBUTION OF FELDSPAR IN CUTTINGS FROM DEEP WELL NEAR ROSEMONT, MINNESOTA (SURFACE ELEVATION, 1,000 FEET)

| | *Depth of Sample in Feet* | *Percentage Feldspar* |
|---|---|---|
| Mt. Simon | 728 | 2.9 |
| | 800 | 2.3 |
| | 833 | 1.9 |
| | 920 | 1.31 |
| Hinckley | 935 | 0.18 |
| | 939 | 0.23 |
| | 975 | 0.14 |
| | 980 | 0.26 |
| | 1,000 | 0.29 |
| | 1,007 | 0.24 |
| | 1,024 | 0.12 |
| Red Clastic | 1,036 | 34.60 |
| | 1,050 | 38.21 |
| | 1,105 | 18.42 |
| | 1,150 | 23.48 |

TABLE VII

PERCENTAGE DISTRIBUTION OF FELDSPAR IN CUTTINGS FROM DEEP WELL AT GLENCOE, MINNESOTA (SURFACE ELEVATION, 1,000 FEET)

| | *Depth of Sample in Feet* | *Percentage Feldspar* |
|---|---|---|
| Mt. Simon | 575–587 | 1.7 |
| | 589–598 | 2.1 |
| | 602–611 | 2.3 |
| | 652–660 | 1.6 |
| | 702–718 | 1.8 |
| | 745–757 | 1.1 |
| Hinckley | 760–770 | 0.26 |
| | 805–817 | 0.34 |
| | 846–859 | 0.21 |
| | 924–930 | 0.19 |
| | 936–940 | 0.13 |
| Red Clastics | 955–965 | 43.2 |
| | 970–985 | 36.7 |
| | 990–1,000 | 38.4 |

Similar percentage distribution of feldspar was found in cuttings from wells at Faribault, Mankato, and Rochester. At Winona the Mt. Simon rests directly on granite with a relationship similar to that which crops out at Chippewa Falls, Wisconsin.

The red color that characterizes the Red Clastic series is not in itself a safe criterion for establishing the base of the Hinckley sandstone. Table VIII shows several zones of red sandstones and shales in typical salmon-colored Hinckley with percentages of feldspar that are similar to those of outcrop samples from that formation in the same vicinity. Red sandstones of Hinckley age are found also in the sections exposed along the Willow and Net rivers.

TABLE VIII

PERCENTAGE DISTRIBUTION OF FELDSPAR IN CUTTINGS FROM FEDERAL PRISON WELL AT SANDSTONE, MINNESOTA (SURFACE ELEVATION, 1,100 FEET)

| | *Depths of Samples in Feet* | *Lithology* | *Percentage Feldspar* |
|---|---|---|---|
| Hinckley Sandstone | 25–75 | Pinkish sandstone | 0.30 |
| | 120–125 | Red sandstone | 0.24 |
| | 125–130 | Red sandstone | 0.21 |
| | 130–135 | Red sandstone | 0.28 |
| | 230–235 | Yellowish pink sandstone | 0.25 |
| | 280–285 | Yellowish pink sandstone | 0.30 |
| | 330–335 | Deep red sandstone | 0.23 |
| | 380–385 | Pink sandstone | 0.26 |
| | 430–435 | Pink sandstone | 0.24 |
| | 460–465 | Pink sandstone | 0.28 |
| | Bottom of well | | |

The feldspar in the Red Clastic series is in the form of highly kaolinized detrital grains of orthoclase, microcline albite, and oligoclase. Orthoclase and microcline predominate. Most of the grains show appreciable abrasion and a few with secondary growth show abrasion of the secondary zone. This relationship indicates that the secondary growth took place at a time prior to its deposition with the Red Clastic sediments. No typical, euhedral, authigenic grains were observed nor were euhedral crystal faces developed on detrital nuclei.

The small amount of feldspar in the Hinckley sandstone is petrographically very similar to that of the Red Clastic series. It likewise contains a few detrital grains with secondary growth, but the added zones are abraded also.

The Mt. Simon feldspars show all of the characteristics of those in the Hinckley and the Red Clastic series, but in addition there is much fresh authigenic feldspar that shows no signs of abrasion and only slight kaolinization. Unabraded secondary growth zones are also conspicuously developed.

As heavy accessory minerals in the Hinckley and Mt. Simon are similar in types and in percentage distribution, they are of no

correlative value. The Red Clastics, however, contain an entirely different heavy-mineral assemblage, that is characterized by a very high percentage of apatite and garnet. These two minerals are very rare in both the Hinckley and the Mt. Simon.

In their study of pre-Cambrian and Cambrian relations in the Upper Mississippi Valley, Atwater and Clement[5] distinguished between the Hinckley of northeastern Minnesota and the Mt. Simon of the St. Croix Valley region mainly on the basis of authigenic feldspar and secondary growth of quartz. Such secondary features are of questionable value in correlation. Using such criteria they concluded that the Hinckley sandstone does not occur in southeastern Minnesota. Because of Atwater and Clement's attempt to include in the Mt. Simon all of the sandstone below the Eau Claire member of the Dresbach and above the Red Clastic series, the present study was undertaken in an attempt to find more positive criteria for distinguishing the sandstone members involved. A quantitative study of feldspar was suggested by the percentage distribution of feldspar from numerous samples taken from typical outcrops of the formation. Petrographic studies reveal that the bulk of the feldspar is a primary constituent of the sediment and therefore of greater correlative value than authigenic feldspar and secondary quartz.

From a study of Tables III–VIII and from other petrographic characteristics it is quite evident that the Hinckley sandstone does not pinch out at the north margin of the Twin Cities artesian basin as postulated by Atwater and Clement, nor, as they suggested, are the sandstones that crop out along the St. Croix Valley similar to those that Winchell,[6] Schwartz[7] and others have referred to as Hinckley in the region of St. Paul and Minneapolis.

The Mt. Simon sandstone forms the basal member of the St. Croixian series and rests disconformably or with a slight angularity on the Hinckley sandstone from the region west of Taylors Falls, and southwestward to Glencoe, and southward at least as far as Rochester and Faribault. Both the Mt. Simon and the Hinckley occur in the Twin Cities artesian basin. From Faribault east toward the Mississippi River valley the Hinckley pinches out against the west-sloping surface of pre-Cambrian granites. Near Winona and north toward Lake City, the Mt. Simon overlaps the Hinckley and rests directly on the granite as it does in large areas in Wisconsin.

[5] *Op. cit.*

[6] N. H. Winchell, "Geology of Minnesota," *Minnesota Geol. Nat. Hist. Survey*, Vol. 2 (1888).

[7] G. M. Schwartz, "Geology of the Minneapolis-St. Paul Metropolitan Area," *Minnesota Geol. Survey Bull. 27* (1936).

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VOL. 24, NO. 4 (APRIL, 1940) PP. 750-755

# REVIEWS AND NEW PUBLICATIONS

* Subjects indicated by asterisk are in the Association library and available, on loan, to members and associates.

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## TEXTBOOK OF PALEOBOTANY, BY WILLIAM C. DARRAH

REVIEW BY ROLAND W. BROWN[1]
Washington, D. C.

*Textbook of Paleobotany*, 1939, by William C. Darrah. 441 pp., 180 illus. Cloth, red. Price, $6.00. D. Appleton-Century Company, New York.

This book is the enlarged and somewhat rearranged material of the author's *Principles of Paleobotany*, published a few months earlier under other auspices. The subject-matter is that utilized in the course of lectures given at Harvard University, and here brought together to serve as a "brief, introductory book on paleobotany." The author states that he has designed his book not for the professional, but for the novice, who, however, is assumed to have acquired "a working knowledge of general botany, the elements of plant anatomy, and some knowledge of historical geology" (pp. vii, viii). In the Foreword the author sounds the keynote to his treatment of the subject, namely, that the approach is biological rather than geological. For this reason, what follows is largely a descriptive catalog of biologic results and theories. The student, interested in the stratigraphic applications of paleobotany, will seek in vain for answers to such questions as: Where and how shall one look for fossil plants, and what constitutes a satisfactory collection? How do paleobotanists apply the results of their studies to the dating and correlating of strata?

Part 1 of the main body of the book includes an introduction, a statement of general principles, and a chapter on the paleobotany of coal. Thin section, peel, transfer, maceration, and microtome methods are described under paleobotanical technique. These obviously are methods of treatment of specimens for microscopic attack. As for methods used in the megascopic preparation and study of specimens, disposal and care of specimens after study, pollen analysis, and nomenclatural problems—all of which would seem to be important to a beginner seeking guidance—little or nothing is said.

Part 2 is a review of the general groups of vascular plants, with special attention to the origin and geological history of the angiosperms, using Rendle's *Classification of Flowering Plants* as a background for the citation of fossil examples. Part 3 recounts the succession of floras from the Paleozoic to the present, and Part 4 discusses some theoretical matters, particularly "a reasonable phylogeny of vascular plants."

Each chapter is supplied with a pertinent bibliography. The illustrations consist of photographs, chiefly new, and redrawn sketches of classical figures. There is a nine-page index.

[1] Geological Survey, United States Department of the Interior. Manuscript received, February 14, 1940.

## WATER SUPPLIES IN 'IRAQ, BY W. A. MACFADYEN

REVIEW BY LINN M. FARISH[1]
Youngstown, Ohio

"Water Supplies in 'Iraq," by W. A. Macfadyen. 206 pp. 8×13 inches, 19 pls., numerous charts. *'Iraq Geological Department Publication 1.* Ministry of Economics and Communications, Government Press, Baghdad, 'Iraq (1938). Price, 250 Fils (5/–), paper bound.

The 'Iraq Geological Department came into existence in the autumn of 1933. Since this date by far the greater part of the geologists' time has been occupied with problems of water supply. This is the most fruitful work on which the Department can be employed and it is entirely fitting that its first publication should be concerning a substance of which an ample supply is so necessary to the life of the country.

The object of the publication, as stated by the author, is to collect in permanent form the results of the Geological Department's work on the water supplies of 'Iraq. It is primarily intended for practical use in 'Iraq so there is much of purely local interest. There are, however, many matters of wider appeal such as the geological map of 'Iraq (scale 1:2,000,000), rainfall data (1888–1936), more than 200 water analyses (all hitherto unpublished), and other general matter. The Provisional Geological Map of 'Iraq is annotated as having been compiled by the 'Iraq Geological Department from various sources, namely: E. H. Pascoe; *Mem. Geol. Survey India,* 43 (1922); L. Dubertret; Carte Geological de la Syrie et due Liban, 1933; many unpublished surveys of the 'Iraq Petroleum Company, 1926–1933 (with their permission); and unpublished work of the 'Iraq Geological Department, 1933–1937.

The description of the kahriz, or infiltration tunnel, is extremely interesting in the light of general information. This ancient and most ingenious method of obtaining flowing water at the surface, that is, an artificial stream, is described in detail. It is reported that, according to Sir Aurel Stein,[2] in southern Iran kehariz date from post-chalcolithic time and were widespread in Iran in Arsacidian time, that is, between 250 B.C. and 230 A.D.

The reviewer has noted and studied a great many of these infiltration tunnels in northern Iran where they are known as ghanats. In their construction a well is sunk by hand to the water table, the site selected usually being on one of the large alluvial fans which attain great prominence along the southern flank of the Elburz Mountains. This shaft with its accompanying mound of earth is locally known as a halgheh chah. The wells are sunk from 50 to 100 feet apart along the line in which it is desired to move the water and are connected by an inclined tunnel. The inclination of the tunnel is slightly less than that of the ground and the water table which results in the tunnel emerging at the surface, usually as a beautifully clear, cold stream of water in what is typically a hot, dry, waterless plain. The amount of water obtained will vary with the character of the reservoir and the time of the year, but yields up to 3 million gallons daily are not uncommon. An experi-

[1] Magnolia Petroleum Company. Publication received, February 23, 1940. Manuscript received, March 14, 1940.

[2] *Geographical Journal,* 83 (1934), p. 124.

enced engineer is immediately impressed by the sound engineering principles which have been used in the construction of the ghanats and the great amount of time and ingenuity needed successfully to complete one of them. These underground water transportation systems are remarkably well suited for the character of the country and date back more than 2,000 years. Constructed as they are with shafts from 150 to 500 feet deep, the entire system extending from a few hundred feet to 20 miles, they must represent the oldest engineering projects still in use and comparable with our present-day practices.

Few new kahriz are dug and, unless a large flow of water can be obtained, which can usually not be guaranteed in advance, it will probably be cheaper in general to sink wells and pump the water. Nevertheless certain favorable areas exist in which short kehariz may probably be constructed to advantage.

As the water supply in 'Iraq is all ultimately derived from the rainfall, these records, mainly unpublished information, have been studied as far as possible and the information correlated. The published charts give the yearly rainfall from 1888 through 1936. It is noted that rainfall is generally restricted to the months between November and May, inclusive, though there may be some in October, mostly in the north of the country. June to September are generally rainless, with no more than rare occasional traces. The average rainfall is heaviest in the north (1,000 millimeters or 39.37 inches in the mountainous Kurdistan region) decreasing to the south and southwest (314 millimeters or 12.36 inches in Mosul and 124 millimeters or 4.88 inches in Baghdad).

Publication No. 1 is composed of Water Supply Reports Nos. 1 to 16 together with supplements and other matter if this gives further information or views as to development of the resources. The various maps accompanying the reports are in both English and Arabic. The size of the areas discussed in each report varies greatly but they aggregate more than half of the total area of the country.

The reports vary in character according to the character of the problem and the size of the area. In general, however, they have the following outline.

Map Reference or Plate
Usually a sketch map showing the details of the area discussed or a reference to a key map

1. Introduction
Usually states the reason and authority for making the survey together with the conditions, personnel, and other physical factors which influenced the work
2. Topography
A general statement outlining the salient topographical features of the area
3. Geology
Observations contained under this heading should be of interest to geologists who are concerned with problems other than those of water supply. Stratigraphy and structure are discussed in varying detail in nearly all reports
4. Rainfall
A general statement as to the amount of rainfall with detailed yearly figures if available
5. Water Supply
Statements as to the character and condition of the sources of the present water supply, the prospects of increasing the available water supplies, and the developing of new sources of supply
6. Summary and Conclusions
This heading, in many reports, is placed at the beginning or considered separately. Usually a concise statement concerning the condition of the present

water supply with conclusions and recommendations concerning its rejuvenation or for developing new sources of supply. An interesting development along the lines of new sources of supply is the proposal to construct a water tight subsurface dam across the Qadha Chai, 4 kilometers upstream of Kirkuk town. This would have the effect of forcing to the surface all the water which is at present running to waste in the river gravels below the surface of the chai. The flow could then be taken off into surface channels and used for irrigation *et cetera* (Supplement No. 3 to Water Supply Report No. 4, p. 64)

Appendix

The water analyses and their interpretation and provisional estimates of the cost of various water-supply schemes

There is a large amount of data contained in this publication which should be of interest and value to geology and allied sciences. It is hoped that the 'Iraq Geological Department will be able to continue the distribution of geological knowledge concerning an area relative to which there is not a large amount of detailed information available to the general public.

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## RECENT PUBLICATIONS

### ARKANSAS

*"Survey of Crude Oils of the Producing Fields of Arkansas," by O. C. Blade and George C. Branner. *U. S. Bur. Mines R. I. 3486* (January, 1940). 40 multigraphed pp., including a map showing the oil and gas fields in southern Arkansas.

### CALIFORNIA

*"Effect of Faulting on Accumulation and Drainage of Oil and Gas in the Wilmington Oil Field," by Read Winterburn. *A.I.M.E. Petrol. Tech.* (New York), Vol. 3, No. 1 (February, 1940). *Tech. Paper 1154*. 17 pp., 5 figs.

*"Tertiary Formations of Northern Sacramento Valley, California," by Charles A. Anderson and R. Dana Russell. *California Jour. Mines and Geol.* (San Francisco), Vol. 35, No. 3 (July, 1939), pp. 219–535; 14 figs., 1 pl.

*"Geology and Oil Possibilities of Caliente Range, Cuyama Valley, and Carrizo Plain, California," by J. E. Eaton. *Ibid.*, pp. 255–74; 5 figs., 1 pl.

### ENGLAND

*"The Geology of the Colwyn Bay District: A Study of Submarine Slumping during the Salopian period," by Owen Thomas Jones. *Quar. Jour. Geol. Soc. London*, Vol. 95, Pt. 4, No. 380 (January 18, 1940), pp. 335–82; 26 figs., Pls. 23–26.

*"The Stratigraphy and Faunal Succession in the Ordovician Rocks of the Builth-Llandrindod Inlier, Radnorshire," by Gertrude Lilian Elles. *Ibid.*, pp. 383–445; 10 figs., Pls. 27–32.

### FLORIDA

"The Molluscan Fauna of the Alum Bluff Group of Florida," by Julia Gardner. *U. S. Geol. Survey Prof. Paper 142-F*, Pt. vi (1940).

### GENERAL

*"Well Logging by Radioactivity," by G. H. Westby and S. A. Scherbatskoy. *Oil and Gas Jour.* (Tulsa), Vol. 38, No. 1 (February 22, 1940), pp. 62–64; 7 figs.

*"Invertebrate Fauna of the Late Permian Whitehouse Sandstone," by Norman D. Newell. *Bull. Geol. Soc. America*, Vol. 51, No. 2 (New York, February 1, 1940), pp. 261–36; 10 pls., 11 figs.

*Reconnaissance Structure-Contour Map of the Surface of the Basement Complex*, compiled by a committee of the American Geophysical Union as Special Exhibit No. 1, for display at the meetings of the International Union, held in September, 1939. Same scale as areal geologic map of United States (1/2,500,000); covers region from Atlantic Coast to western edge of Colorado Plateau, or eastern edge of Great Basin. Black-and-white, on four sheets (26×36 inches each). Price $4.00—postpaid in United States. J. A. Fleming, general secretary, American Geophysical Union, 5241 Broad Branch Road, Washington, D. C.

GEORGIA

*"*Geologic Map of Georgia* (1939), prepared by the Georgia Division of Mines, Mining, and Geology, in coöperation with the United States Geological Survey. Sheet, 41×45 inches. Scale, 1:500,000. In colors. Includes a stratigraphic columnar section and a structural cross section. Price, $1.10, postpaid.

GERMANY

*"The South Part of the Salt Plugs of Benthe-Gehrden: a Report on the Knowledge of the Rising of Hannover Salt Plugs," by Leonhard Riedel. In German. *Oel und Kohle* (*Petroleum*), Vol. 36, No. 3 (Berlin, January 15, 1940), pp. 27–33; 2 figs.

GULF COAST

"The Venericardia Planicosta Group in the Gulf Province," by Julia Gardner and Edgar Bowles. *U. S. Geol. Survey Prof. Paper 189-F* (1940).

"Notes on Fossils from the Eocene of the Gulf Province," by Julia Gardner, *Ibid.*, *193-B*.

ILLINOIS

"Structure of Herrin (No. 6) Coal Bed in Randolph, Western Perry, Southwestern Washington, and Southeastern St. Clair Counties, Illinois," by G. H. Cady, with "Notes on Oil and Gas Possibilities," by A. H. Bell. *Illinois Geol. Survey Circ. 58* (Urbana, March 11, 1940). Circular, *gratis*. Structure map, 40×40 inches, blueprint, $0.60.

*"Gas Injection at Loudon, Illinois," by R. J. Sullivan. *A.I.M.E. Petrol. Tech.* (New York), Vol. 3, No. 1 (February, 1940). *Tech. Paper 1173*. 15 pp., 8 figs.

JUGOSLAVIA

*"The Occurrence of Bituminous Shale in the Lika," by Gr. Petunnikov. In German. *Oel und Kohle* (*Petroleum*), Vol. 36, No. 1 (Berlin, January 1, 1940), pp. 6–9; 5 figs.

KANSAS-NEBRASKA

*"Forest City Basin Chances Enhanced by Oil Strike," by Hugh McClellan. *Oil Weekly* (Houston), Vol. 96, No. 13 (March 1, 1940), pp. 17–20, with geological section and map.

LOUISIANA

*"Deepening and Completing a Well in the Lisbon Field, Louisiana—

a Study in Modern Coöperative Practice," by Paul D. Torrey and Frank H. Miller. *Petroleum Engineer*, Vol. 11, No. 5 (Dallas, February, 1940), pp. 155–68; 2 figs., 11 tables. Pt. I.

MISSISSIPPI

*"Yazoo County Mineral Resources," *Mississippi Geol. Survey Bull. 39* (1940). "Geology," by Frederic Francis Mellen. "Tests," by Thomas Edwin McCutcheon. 132 pp., 17 figs., 2 pls.

MISSOURI

*"Summary, Oil and Gas Test." 5 mim. pp. containing a summary description, including the tops of geological formations in 5 oil and gas tests in northwest Missouri in 1939. *Missouri Geol. Survey* (Rolla, February 23, 1940). Price, $0.05 each.

MONTANA

"The Mizpah Coal Field, Custer County, Montana," by F. S. Parker and D. A. Andrews. *U. S. Geol. Survey Bull. 906-C* (1939 [1940]), pp. 85–133, Pls. 16–40, Figs. 18–22. Supt. Documents, Govt. Printing Office, Washington, D. C. Price, $1.50.

NEVADA

*"Devonian Stratigraphy and Paleontology of the Roberts Mountains Region, Nevada," by C. W. Merriam. *Geol. Soc. America Spec. Paper 25* (New York, February 29, 1940). 114 pp., 7 figs., 16 pls., 8 tables.

NEW MEXICO

*"Tertiary Geology of the San Acacia Area, New Mexico," by Charles S. Denny. *Jour. Geol.* (Chicago), Vol. 48, No. 1 (January-February, 1940), pp. 73–106; 10 figs.

OKLAHOMA

*"Seminole Proving Ground for New Practices," by W. V. Howard. *Oil and Gas Jour.* (Tulsa), Vol. 38, No. 1 (February 22, 1940), pp. 39–40; 58; 3 illus.

POLAND

*"A Gravity Map of Poland and Observations on the Southern Extension of the Templeburger Axis," by H. Cloos and R. V. Zwerger. In German. *Oel und Kohle* (*Petroleum*), Vol. 36, No. 1 (Berlin, January 1, 1940). pp. 2–6; map.

TEXAS

*"Disposal of Salt Water in the East Texas Field," by A. S. Rhea and E. B. Miller, Jr. *A.I.M.E. Petrol. Tech.* (New York), Vol. 3, No. 1 (February, 1940). *Tech. Paper 1151.* 10 pp., 3 figs.

URUGUAY

*"Bibliographie Géologique de la République Orientale de l'Uruguay," by Roger Lambert with the collaboration of Jorge Aznárez. *Geol. Inst. Uruguay Bol. 26* (Montevideo, August, 1939). 81 pp. Contains 282 annotated (in French) bibliographic references.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 24, NO. 4 (APRIL, 1940), PP. 756-761

# THE ASSOCIATION ROUND TABLE

## MEMBERSHIP APPLICATIONS APPROVED FOR PUBLICATION

The executive committee has approved for publication the names of the following candidates for membership in the Association. This does not constitute an election but places the names before the membership at large. If any member has information bearing on the qualifications of these nominees, he should send it promptly to the Executive Committee, Box 979, Tulsa, Oklahoma. (Names of sponsors are placed beneath the name of each nominee.)

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Louis Hosea Desjardins, Tulsa, Okla.
W. B. Wilson, Robert H. Wood, James H. Gardner
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S. K. Clark, Glenn C. Clark, Everett C. Parker
Julius Anthony Heeren, Tulsa, Okla.
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Loyal Edward Nelson, Bakersfield, Calif.
James R. Dorrance, W. S. Olson, E. R. Baddley
Alice Quesenbery, Bartlesville, Okla.
Charles E. Decker, Robert L. Kidd, A. K. Wilhelm
William M. Schulz, Mt. Pleasant, Mich.
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George C. McGhee, Ward R. Vickery, O. C. Clifford, Jr.

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Herbert Mack Cox, El Dorado, Ark.
W. B. Weeks, Clarence O. Day, Hal P. Bybee
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Thomas C. Matson, Tulsa, Okla.
W. B. Wilson, A. I. Levorsen, James H. Gardner
James W. McHugh, Mattoon, Ill.
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Stafford Park, Long Beach, Calif.
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Charles William Seedle, Shreveport, La.
H. R. Kamb, A. C. Trowbridge, A. K. Miller
Lyle Wyman Smith, Ventura, Calif.
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George Terrell Thomas, Lubbock, Tex. (West Texas Geological Society Merit Award Application)
Leroy T. Patton, Raymond Sidwell, M. A. Stainbrook
James Robert Tichy, Amarillo, Tex.
E. W. Rumsey, E. F. Schramm, R. E. Shutt
Robert Alfred Whitlock, Jr., El Paso, Tex. (West Texas Geological Society Merit Award Application)
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A. P. Allison, James D. Aimer, S. A. Packard

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## MISSISSIPPI GEOLOGICAL SOCIETY CRETACEOUS FIELD TRIP, MAY 3, 4, AND 5, 1940

All persons attending the Cretaceous field trip of the Mississippi Geological Society will gather at the Lamar Hotel in Meridian, Mississippi, on the evening of May 2, 1940. The party will start from the Lamar Hotel promptly at 8:00 A.M., Friday, May 3, 1940. The group will see the entire Upper Cretaceous section from Livingston to Tuscaloosa, Alabama, where the deposits above the Eutaw are all chalk. The first night will be spent in Columbus, Mississippi.

On May 4, the section from Fulton to New Albany will be studied. In this area, the section above the Eutaw consists of alternating beds of sand and chalk. The second night will be spent in Tupelo, Mississippi. A talk on the stratigraphy of the Upper Cretaceous will be given on the evening of May 4, at Tupelo, Mississippi, by the leader of the Cretaceous field trip, Watson Monroe of the United States Geological Survey.

On May 5, the party will see replacement of fossil shells by beidellite at Ponotoc, and, if roads are passable, the group will visit the classic Owl Creek type locality.

Field-trip guide books will be on sale Thursday evening at the Lamar Hotel, and during the field trip. All available five-passenger automobiles will be used in order to cut down the number of vehicles.

Mr. Monroe will give approximately the same talk on the stratigraphy of the Upper Cretaceous at the regular meeting of the Mississippi Geological Society at the Edwards Hotel in Jackson, May 8. This talk will be given for the benefit of those members of the Mississippi Geological Society who are unable to attend the field trip.

So that some idea may be had of the number of persons attending, it would be appreciated if the following information is sent to Tom McGlothlin, P.O. Box 1105, Jackson, Mississippi.

1. Name and address of person planning to attend.
2. Number of guide books desired.
3. Individual will drive his own car or transportation will be needed.
4. Reservation will be needed at Meridian, Columbus, Tupelo.

## ASSOCIATION COMMITTEES

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| 1940 | 1941 | 1942 |
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### COMMITTEE STUDYING METHODS OF ELECTING OFFICERS

WALTER R. BERGER, *chairman*, Trinity Building, Fort Worth, Texas

R. M. BARNES A. R. DENISON C. E. DOBBIN

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 24, NO. 4 (APRIL, 1940), PP 762-764

# AT HOME AND ABROAD

## CURRENT NEWS AND PERSONAL ITEMS OF THE PROFESSION

GEORGE S. BUCHANAN has resigned as vice-president in charge of exploration for the Adams Oil and Gas Company, Houston, Texas, and has opened offices on the 13th floor of the Esperson Building with GEORGE HARRISON, as consulting geologist and geophysicist. Harrison was recently in charge of the geophysical department of the Barnsdall Oil and Gas Company.

G. H. WESTBY, president of the Seismograph Service Corporation, spoke on "Well Logging by Radioactivity" before the Mid-Continent Section of the A.I.M.E. at Tulsa, March 11.

EARL KIPP, of the Standard Oil Company of Texas, has been transferred from Midland to Houston, where he is a petroleum engineer in the Gulf Coast division.

DAVID G. HAWTHORN, development engineer for the Amerada Petroleum Corporation, spoke before the Shawnee Geological Society, Shawnee, Oklahoma, March 1, on "Continuous Electrical Logging While Drilling."

LUIS E. KEMNITZER, for several years geologist for the Petrol Corporation in California and formerly with Henry L. Doherty and Company, foreign department, in Canada and Germany, has opened an office as consulting geologist at 704 South Spring Street, Los Angeles, California.

FRED W. BATES, consulting geologist of Lafayette, Louisiana, gave a paper on "The Geology of the Eola Field, Avoyelles Parish, Louisiana," at the regular monthly meeting of the South Louisiana Geological Society at Lake Charles, February 20.

H. D. HAND, recently of the Moore Exploration Company, has moved from Midland to Iraan, Texas.

JOHN EMERY ADAMS, president of the West Texas Geological Society at Midland, has selected the following members to represent the society in awarding A.A.P.G. associate memberships to qualified student geologists of the Texas Technological College at Lubbock and the Texas School of Mines at El Paso: BERTE R. HAIGH, chairman; W. C. FRITZ, and FRED F. KOTYZA.

The Oklahoma City Geological Society took a field trip to the Wichita Mountains on March 15 and 16. On the 14th, a preliminary gathering at the Midland Hotel, Lawton, Oklahoma, discussed the geology of the area under the leadership of CHARLES E. DECKER, of the University of Oklahoma. General chairman of the trip was GRAYDON H. LAUGHBAUM, of the Sinclair Prairie Oil Company. MURRAY J. WELLS, Indian Territory Illuminating Oil Company, was in charge of the road log; F. MABRY HOOVER, in charge of lodging and meals; I. CURTIS HICKS, in charge of mapping; and WALTER L. MOREMAN, in charge of registration.

The Mississippi Geological Society held a field trip, March 9 and 10. The itinerary included Jackson, Meridian, Philadelphia, Louisville, Acker-

man, Winona on the first day, and Grenada, Winona, and West Station, with a short side trip into Attala County, on the second day. The officers of the society are: president, HENRY N. TOLER, Southern Natural Gas Company; vice-president, URBAN B. HUGHES, consulting geologist; secretary-treasurer, TOM MCGLOTHLIN, Gulf Refining Company.

W. V. HOWARD, recently engaged in geological consulting practice, is now devoting full time as associate editor of the *Oil and Gas Journal*, Tulsa, Oklahoma. He has an article in the issue of March 7, entitled "Geology Can Do More Than Discover Oil."

RUSSELL TARR, consulting geologist of Tulsa, recently discussed the geology of Kiowa County, Oklahoma, before the Oklahoma City Geological Society.

HENRY A. LEY, president of the Association, recently discussed "Appraisal and Evaluation Background" before the Houston Geological Society.

A. C. HORNADAY, district geologist for the Phillips Petroleum Company, and D. J. MACNEIL, district geologist for the Shell Oil Company, Inc., both of Wichita Falls, spoke at the monthly meeting of the North Texas Geological Society, February 8.

ERNEST A. OBERING, geologist for the Shell Oil Company, Inc., Tulsa, addressed the Panhandle Geological Society, at Amarillo, Texas, February 29, on the subject, "Salt Deposition of the Permian Seas."

MALVIN G. HOFFMAN, recently chief geologist of the Midco Oil Corporation, Tulsa, has resigned that position. He may be addressed at 1321 South Quaker Avenue, Tulsa, Oklahoma.

DONALD G. GIBSON, of the Stanolind Oil and Gas Company, has been transferred from Lubbock, Texas, to Tulsa, Oklahoma.

FRED F. KOTYZA, secretary-treasurer of the West Texas Geological Society, Midland, Texas, will sponsor a field trip into the Sacramento Mountains, between Alamogordo and Cloudcroft, New Mexico, in the latter part of May.

IRA H. CRAM, of The Pure Oil Company, talked on "Regional Structure of the Mid-Continent Area" before the Tulsa Geological Society, March 18.

C. T. JONES, of the Stanolind Oil and Gas Company, has moved from Casper, Wyoming, to 429 First National Bank Building, Wichita, Kansas.

KATHLEEN KIRK has resigned from the Superior Oil Company at Corpus Christi to accept a position with the Standard Oil Company of Kansas at Houston, Texas.

SIDNEY PAIGE sailed from New York, March 21, for the Canal Zone as consultant on geologic problems affecting design of foundations for the new lock system. He will return to New York about May 25.

JAMES M. DORREEN of the New Zealand Petroleum Company, Gisborne, New Zealand, has been granted the degree of Master of Science with Honours by the New Zealand University.

The Indiana-Kentucky Geological Society met at Evansville, Indiana, March 15. P. L. DANA and E. H. SCOBEY, of the Gulf Refining Company of Mattoon, Illinois, presented "A Cross Section of the Chester of the Illinois Basin." There were 71 members and guests in attendance.

STANLEY ELDER, of the Sun Oil Company, Evansville, Indiana, has been elected secretary-treasurer of the Indiana-Kentucky Geological Society to fill the position vacated by the resignation of W. KEITH MILLER who has moved his headquarters to Robinson, Illinois.

H. L. GENTRY, of the H. L. Gentry Engineering Company, 921 East Michigan Avenue, Jackson, Michigan, was erroneously listed in the membership list of the March *Bulletin* as being in Mississippi. He lives at Jackson, Michigan.

During the week of March 4, A. I. LEVORSEN, consulting petroleum geologist of Tulsa, Oklahoma, delivered three lectures at the University of Chicago and Northwestern University. The titles were: "The Petroleum Geologist," "Some Frontiers in Petroleum Geology," and "Studies in Paleogeology."

RALPH A. LIDDLE has returned to New York after spending 3 months in the interior of Eucador exploring oil concessions.

CONRAD BILGERY, S. J., spoke before the Rocky Mountain Association of Petroleum Geologists, Denver, Colorado, March 18, on "Some Contributions to the History of the Pleistocene of the Denver Basin."

CHESTER SAPPINGTON, recently with the Petty Geophysical Engineering Company, is now vice-president in charge of field work for the General Geophysical Company, Gulf Building, Houston, Texas.

E. O. BUCK and A. S. PARKS have organized the firm of Gas Laboratories, Inc., with offices in the Commerce Building, Houston, Texas.

E. F. MILLER, geologist for the Oliphant Oil Corporation, Shreveport, Louisiana, presented a paper on "The Cotton Valley Field, Webster Parish, Louisiana," before the Houston Geological Society, Houston, Texas, early in March.

F. W. MICHAUX, JR., formerly vice-president in charge of operation for the Navarro Oil Company, Houston, Texas, is president of F. W. Michaux, Inc.

MARCUS A. HANNA, geologist with the Gulf Oil Corporation, Houston, spoke before the Mississippi Geological Society, Jackson, Mississippi, early in March on "Geology of the Claiborne Formation."

CECIL HAGEN, chief exploration geologist for the Superior Oil Company of California, Houston, Texas, has resigned and opened a consulting office in the Gulf Building, Houston.

BRANDON GROVE, geologist for the Socony-Vacuum Oil Company, discussed "European Oil Fields" before the Oklahoma City Geological Society, early in March.

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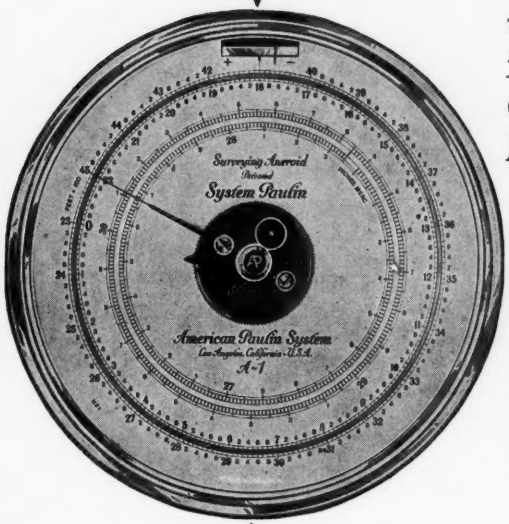


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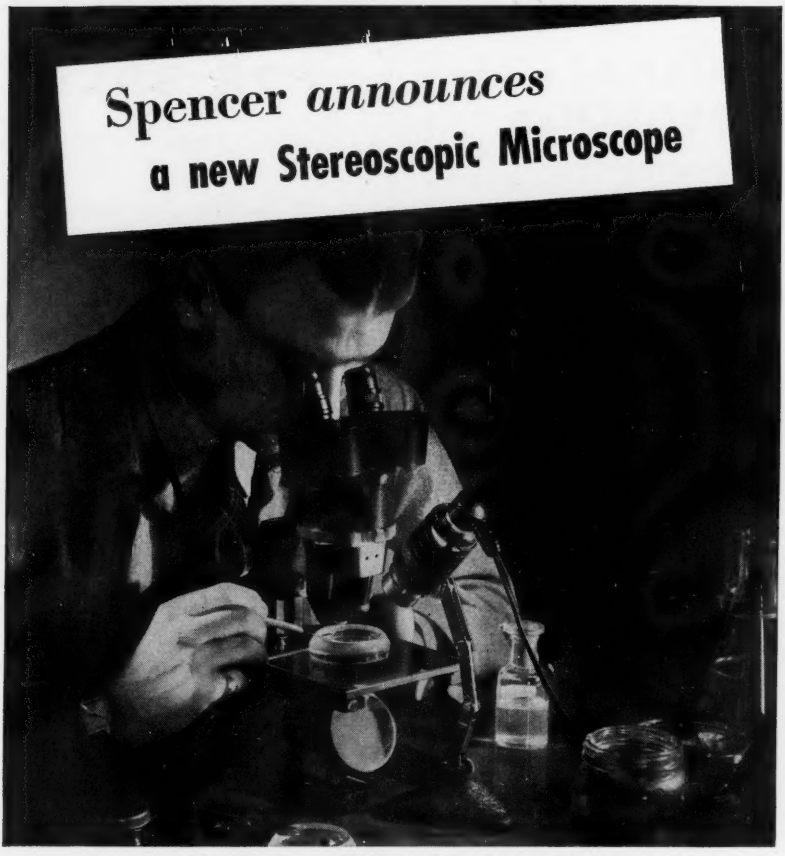


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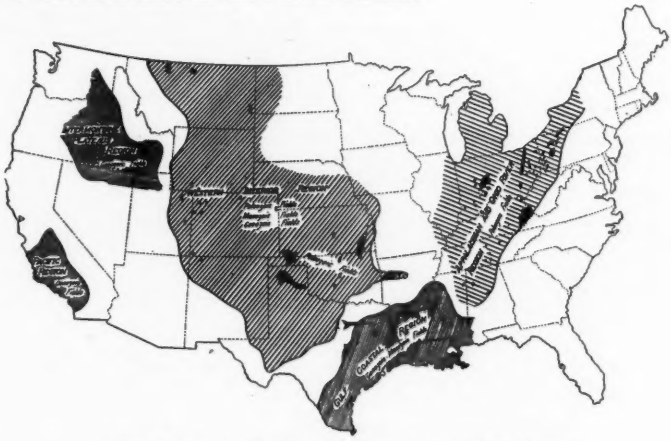

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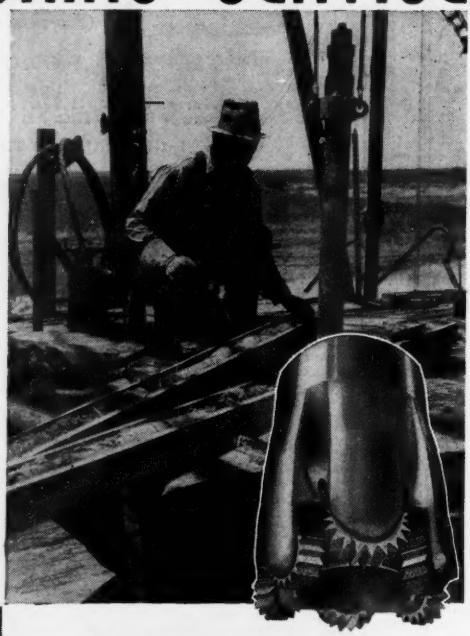

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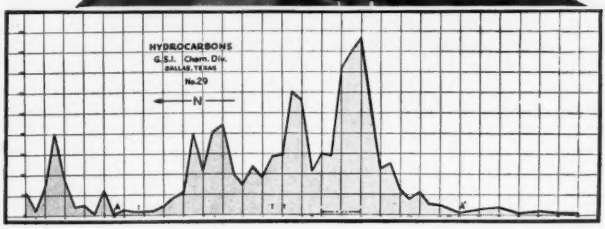


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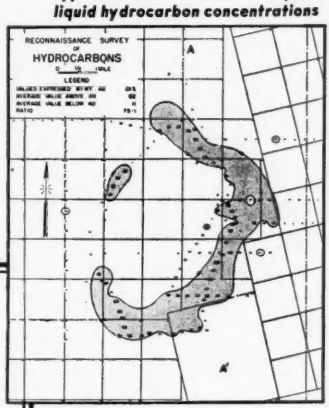


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